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On Photographs of the Brighter Planets by Light of Different Colours. (George Darwin Lecture, delivered by Professor W. H. Wright on 1928 June 8). (Plates 14–16.)

The methods with which we have to do in the discussion this afternoon have for years been applied in general scientific observation. They occupy ground between precise spectroscopy on the one hand and the more versatile means of analysis provided through the perception of form and colour by the eye on the other. The spectroscope is by far the most powerful and accurate instrument that exists for the study of radiation, but while its indications are, in a sense, absolute, they do not in general, or without the multiplication of observations, give information relating to form and distribution. While supplying these deficiencies, the evidence provided by the eye requires for its interpretation knowledge derived from other sources. A series of photographs taken with approximately homogeneous light of distinct spectral regions has an advantage over the coloured presentation provided by ordinary visual perception in that its several images are separate, but its testimony, like ocular evidence, must be interpreted in the light of independently derived knowledge. It is well known that any object of diversified colour will suffer an apparent alteration in the contrasts of its several parts if the colour of the light by which it is viewed is changed. This is a natural consequence of the phenomenon of colour. Photography provides an especially suitable means for observing such alterations because it renders them in uniform terms of photographic density. Very marked differences are occasionally found when the colour used in photographing is altered, and it is sometimes possible, through a study of these differences, to learn something of the body under observation.

In taking the photographs that illustrate these remarks the several colours used were isolated by the employment of filters in conjunction

with plates of suitable colour sensibility. This method of observation has had a wide application in astronomical practice, and has been used in the study of such diverse objects as the diffuse nebulæ, the spiral nebulæ, star clusters, single stars, and the planets. Yellow or orange filters have long been employed in the photographic study of the latter, but that has usually been for the purpose of overcoming the limitation of refracting telescopes that is imposed by chromatic aberration. However, in 1912, Professor R. W. Wood secured monochromatic photographs of the Moon for analytical purposes, and followed in 1915 with similar observations of Jupiter and Saturn. Wood's work was important in calling attention to the possibilities of monochromatic photography as a means of studying the planets, and it is rather surprising that immediate advantage of the suggestions it provided was not taken by observers of planetary phenomena.* The present observations were begun, without previous experience in the observation of planets, at the apparition of Mars in 1924, and were continued, with the inclusion of other planets, in 1926 and 1927.

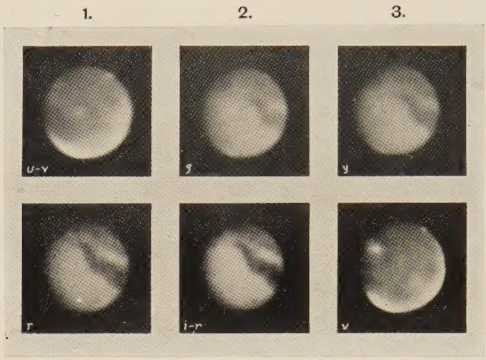
Mars.

In figs. 1 to 6 are shown photographs of Mars taken by light of six different regions of the spectrum. The spectral positions are approximately defined by the colours, which are, in order, ultra-violet, green, yellow, red, infra-red, and violet. The wave-length of the ultra-violet light used is approximately 3700 Å., which lies just beyond the limit of visibility to the eye. By "violet" will be understood the entire range of colour, including a certain amount of blue, to which ordinary photographic plates are sensitive. The designations "green," "yellow," and "red" are probably sufficiently specific to suggest the respective parts of the spectrum used, while the term "infra-red" refers to a narrow region of the spectrum near 7600 Å., at the extreme limit of the eye's sensitivity.† The photographs of this series are arranged substantially in the order in which they were taken, which is, except in respect to the last of them, the spectral sequence of the colours used.

It will be seen that there are progressive changes from the first to the fifth photograph. Those that relate to the position of the markings are readily recognised as being due to the planet's rotation on its axis. The axis passes upward to the right, and approximately through the centre of the polar cap, which is seen on some of the photographs as a small white dot on the planet's edge; and the effect of rotation is to displace the markings of successive images upward to the left. After allowing for these displacements, there remain differences of a more fundamental character that will now be considered. Figs. 5 and 6

* After the presentation of this paper my attention was kindly called by Mr. Reynolds to some monochromatic photographs of Jupiter made by him in the year 1919. See *M.N.*, **80**, 200.

† The filters and plates used to isolate these several colours are specified in *Lick Observatory Bulletin*, No. 389.



Figs. 1–6.—Mars photographed by light of different colours, 1926 Oct. 16.

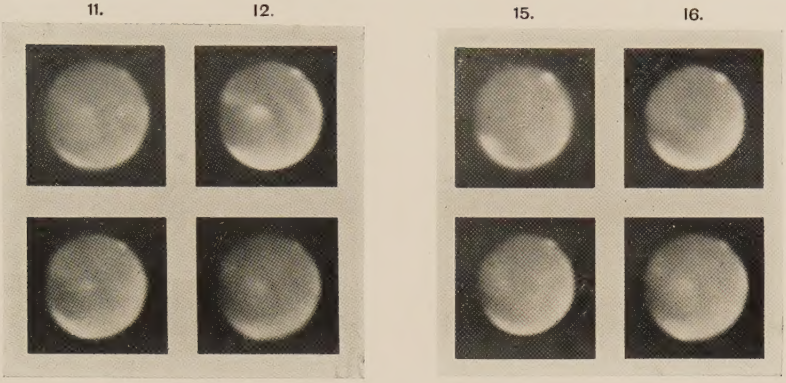
Moon.

Fig. 7.—u-v light. Fig. 8.—i-r light.

1926 Sept. 17.

San José from Mt. Hamilton.

Fig. 9.—Violet light. Fig. 10.—Infra-red light.



Mars (Cloud Pictures).

Figs. 11-14.—1926 Oct. 14, 15, 16, 18.

Figs. 15-18.—1926 Oct. 18.
5h. 57m.; 7h. 40m; 8h. 3m.; 9h. 51m.

Mars, 1926 Nov. 2, 3.

Fig. 19.—i-r light. Nov. 2.

Fig. 20.—u-v light. Nov. 2.

Fig. 21.—i-r light. Nov. 3.

Fig. 22.

Sierra Nevada Mountains and Yosemite Valley, taken from Mt. Hamilton by infra-red light.

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were taken so closely together in point of time that they provide substantially identical presentations of the planet, and the disparity in their appearances is one that it would be very difficult to explain as a consequence of the different colours of its several parts. Reduced contrast of markings against the bright background would be expected in a violet photograph because of the bluish-green colour in which the telescope reveals them, but the total obliteration of all structure shown in the infra-red image, and the substitution of something of an entirely different kind, seems difficult to explain as a colour effect. This phenomenon is, to the best of my knowledge, unique, and peculiar to Mars. Perhaps an illustration of what is found in the case of the Moon, where, it may be remarked, serious disturbance by an enveloping atmosphere is not to be expected, will be of interest. Photographs of the Moon, taken by ultra-violet light and by light of the infra-red, are shown in figs. 7 and 8. The two are substantially identical, such differences as exist being in minutiæ of structure that must be searched for carefully. In the case of Jupiter, if we may anticipate for a moment a subject which will be more fully discussed later, we find very remarkable differences, but not complete obliteration and substitution such as is found for Mars.

I think it likely that some of those present this afternoon are familiar with an explanation that has been offered of the extinction of surface detail in the blue and violet images of Mars, and with a certain group of photographs that has served to illustrate it. I shall accordingly ask their indulgence for the following brief statement of that explanation, which is made in the interest of completeness. Figs. 9 and 10 are photographs of a terrestrial landscape taken with violet and infra-red light respectively. In 9 the more distant parts of the landscape are obliterated by the earth's atmosphere ; the middle and upper part of the picture may in fact be regarded as a photograph of the atmosphere viewed in considerable thickness. In view of this explanation a comparison of 9 and 10 with 6 and 5 suggests that an atmosphere on Mars, long ago inferred by observers of the planet to be present, is sufficiently dense to hide the surface in the blue and violet photographs. This interpretation has not been passed by others without question, but it is not my purpose here to contend against criticism, for a mere statement of the points at issue would consume a large part of our available time. Furthermore, a controversial attitude might suggest that your speaker holds convictions in relation to the existence of one or another condition on the planet, which is not the case. Convictions are, as a rule, inconvenient incumbrances to one who has to do with the interpretation of natural phenomena. They attach themselves to his consciousness and in some subtle way manage to invoke the protection of his loyalty. What I should like to do this afternoon is first and foremost to show you some photographs made with the Crossley Reflector of the Lick Observatory ; and second, to present a line of thought that has been suggested by them. In this presentation it will be convenient " in order that ordinary forms of speech may not be fettered by continual qualification," if I may borrow the well-

turned phrase of another, to outline my reflections rather directly and positively, and to depend on these immediate comments to soften the representation to a semblance of my actual view.

It will have occurred to those of you who are experienced photographers that in comparing photographs made under such different conditions as these allowance must be made for the different contrast factors of the several kinds of plates used. To provide for this, areas of graduated intensity were photographed on the original negatives. The intensity ratio between successive areas in all photographs is as 2 to 1. In copying two or more photographs for comparison with one another, an attempt is made to equalise the contrasts in the series of standard areas by the use of suitable plates and developers. In other words, hard negatives are copied on soft plates and *vice versa*, the test for proper contrast being provided by the standard areas, so that the illustrations, as they appear, may be regarded as reasonably free from the effect of differences in the contrast factors of the plates used in taking the original negatives.

It will be well to summarise here some of the principal points of difference that can be recognised in a series of photographs such as that illustrated in figs. 1 to 6.

1. Excepting the polar caps and limb light, the familiar features of the planet are invisible in the ultra-violet photographs, but appear, and become increasingly conspicuous, as the wave-length of the light used in observation increases.

2. The polar caps and limb light are, on the other hand, strong in the ultra-violet photographs, and weaken with increasing wave-length.

3. Ultra-violet and violet photographs record at times whitish areas and mottlings which have been found to be temporary. These, like the polar caps and limb light, decrease in strength with increasing wave-length.

4. When the planet is near opposition there is a pronounced fading, or darkening, at the limb in the red and infra-red images.

5. The ultra-violet and violet images are noticeably larger than those taken by red and infra-red light.

Taking these items in order, the first is perhaps sufficiently explained by the suggestion of an obscuring atmosphere.

With respect to the second, if we assume that the violet and ultra-violet photographs provide a record of the planet's atmosphere, it follows that the polar caps are, partly at least, atmospheric phenomena. That an atmospheric phenomenon of the sort need not destroy the visibility of the surface in light of longer wave-lengths is suggested by the clearness with which the Mare Cimmerium, which is at the right end of the dark marking in figs. 2 to 5, is seen through the limb light depicted in the violet and ultra-violet images. That the limb light is due to local unhomogeneities in the Martian atmosphere is shown in its irregular or lumpy occurrence on the planet's edge, and that it is the product of condensation of some atmospheric constituent is strongly indicated by the fact that it is seen best on the morning horizon, especially in the vicinity of the winter pole.

The whitish areas referred to under item 3 are exceptionally well shown in figs. 1 and 6. They are regarded as atmospheric unhomogeneities near the upper surface of the atmosphere, and will for convenience be termed "clouds," using that word in its general sense and without implication that they are of the nature of the aqueous clouds of our own atmosphere. You will possibly be able to trace the clouds of the first photograph through the second and third, which were made by green and orange light respectively, but I believe not further. On the last photograph of the set the cloud is seen on the terminator, having been carried there by the planet's rotation. It will be found to be very much brighter there, and one was at first disposed to attribute this strength to the fact that in this position it is seen end on, but its behaviour on another occasion, which will be referred to in this paper, has suggested that there was an actual increase in strength during the Martian day.

The two sets of photographs 11 to 14 and 15 to 18 provide interesting studies of this cloud. The first group consists of photographs taken by violet or ultra-violet light on four different days at instants when the areographic presentation of the planet was substantially the same. They show that the cloud persisted with little change for four days as a phenomenon in a certain areographic position at a certain time of the Martian day. Passing now to the second set, fig. 18 is a replica of 14, while 15, 16, and 17 show the planet earlier in the day on which that photograph was taken. Making allowance for the planet's rotation, which during the interval between 15 and 18 was slightly less than 60°, it is seen that the bright cloud which is nearly central on 18 is not found on the early photographs of the same day. It appears to have formed at about Martian noon. Reverting now to the apparent increase in strength shown by a comparison of figs. 1 and 6, of October 16, it seems likely that the increase in strength there indicated was real, and not an effect of perspective. The observations taken together suggest that the cloud in question was a convection phenomenon of the Martian afternoons, recurrent over several days. The greater strength of this cloud at sunset, and of the general limb light at sunrise, suggests that the two phenomena are quite different, and that the atmosphere of Mars, like other planetary atmospheres, is a somewhat complex affair.

Photographs now on hand provide material for the study of one part or another of this cloud group over a period of twenty days, but time will not permit a further reference to the subject here. It is convenient to designate as "blue" clouds those that appear to best advantage in photographs of shorter wave-length. Since these photographs are interpreted as representing the upper atmospheric regions, the blue clouds are regarded as high-level phenomena.

A temporary object of a different kind is shown in fig. 19, a picture taken by infra-red light. By inclining one's head to the right a configuration suggestive of a stag's head and antlers can be recognised, and the object referred to is seen at the stag's throat. Fig. 21, also by infra-red light, was taken on the following day, and the white spot

is found not to be present. The intermediate photograph was taken directly after the first, and was made by ultra-violet light; had the object been a "blue cloud" it would have been recorded with great distinctness, but it is, in fact, quite invisible. In the telescope this object appeared yellowish or orange coloured, matching the shade of the planet's brighter parts, but very much brighter. There is reason to believe that it is one of the yellowish clouds familiar to observers with the telescope. Since it does not appear in the ultra-violet photograph it is assumed that it occurred at a comparatively low level, that is to say, well below the upper surface of the atmosphere. At the Lowell Observatory, in 1922, a yellow object, whose mobility left no doubt of its cloud-like character, was photographed in yellow and in violet light by E. C. Slipher, and was found to exhibit colour reactions similar to those just described. It is interesting to note that the heights of three of these yellow clouds have been determined at the Lowell Observatory, and found to be in the neighbourhood of 15,000 ft. (4500 metres). So considerable an altitude, and many other circumstances as well, make it extremely unlikely that these objects are dust clouds, blown from the surface of the planet by winds, as they were supposed to be by Lowell. In the present state of our knowledge, as permissible a conjecture as any is perhaps that they are aqueous clouds; but if we make that assumption we must account for their decidedly yellow tinge, for aqueous clouds are white. It seems difficult to provide an explanation other than that the atmosphere of Mars serves as a sort of yellow screen, which lends its colour to objects seen through it. The suggestion of a yellow atmosphere is a very old one, but was long ago regarded as disproved by the whiteness of the polar caps. With respect to this objection it may be said, however, that there appears to be a sufficient amount of blue light in the atmospheric element of the polar cap to neutralise the yellow colour in which the surface element alone might be expected to present itself to an outside observer. The specific form that I have elsewhere given to the hypothesis of a yellow atmosphere is that the atmospheric absorption increases with decreasing wave-length, though there are some indications of a maximum transparency in the orange, with decrease on either side. I should like to emphasise the tentativeness of this theory, which is, in some respects, difficult to defend, but which, if allowed, appears capable of explaining much of the appearance of the Martian surface, including the orange colour of the brighter parts and the blue-green tinge of the dark areas.

Let us now consider the fourth item on our list: The darkening of the limb in the red and infra-red images. This must quite certainly be due to atmospheric absorption. If it were some sort of edge effect peculiar to light of this colour, as has been suggested, we should expect to find it in photographs of the Moon, which are in fact free from it. Rough estimates made from successive photographs that record emergence of detail from the obscurity of the limb as the planet rotates, indicate that an absorption of 50 per cent. (for light of 7600 Å.) might be expected to result from vertical transmission through three Martian atmospheres, or, if one may use the term, through three Martian air

masses. If we look to the clear, uncontaminated atmosphere of the earth, the absorptive effects are of no such magnitude. One can readily calculate them for various thicknesses, but it is, perhaps, easier to illustrate the point by a photograph of a landscape.

In fig. 22 we have a picture of the Sierra Nevada Mountains taken from the Lick Observatory by infra-red light of the wave-length used in photographing the planets. The distance to the crest of the range is 135 miles, which, at a rough estimate, is the equivalent of 17 or 18 air masses, approximately the amount a planetary observer would have to look through to see the limb of the earth. When the picture was taken the sun was very low, and directly behind the camera, so that the light had to traverse the atmosphere in both directions. The photograph shows some snow a few feet away, and some in the extreme distance, and there seems to be no great falling off in brightness under these extreme conditions ; certainly the distant snow is not reduced to the tone of earth or rock close by, while on Mars approximate equality is presumably obtained by a difference in path of a little more than three atmospheres. It is believed to be a fair inference from this and other evidence that the atmosphere of Mars is much more opaque than pure air to deep red light. With respect to violet light, such as is effective in ordinary photography, more detail can be discerned on terrestrial photographs taken on a clear day through two air masses than on photographs of Mars through its single vertical atmospheric thickness. As to the impression made on the eye, I may say from personal observation that the visibility of detail on the floor of the Santa Clara Valley, as seen from Mount Hamilton through two air masses on a hazy day, compares favourably with that seen on Mars with the telescope. The suggestion of the several lines of evidence is that the obliterating effect of the Martian atmosphere is, for all available colours, much greater than that of the pure air of the earth. I would have it understood that I am here giving merely my impressions. Atmospheric obscuration is a phenomenon of the greatest complexity and involves, in its simplest analysis, true absorption and scattering, matters about which we really know very little. On examining the edge fading of red and infra-red images it is, however, difficult to escape the conclusion that in those colours we have to do with absorption without very much scattering. If this is so, problems seem to be raised in relation to the relative amount of the sun's radiation that is absorbed in the atmosphere and at the surface of Mars, the consequent distribution of temperature between the two, and the interpretation to be made of observations of the planet's radiation.

In regard to item 5, namely, the excess in size of violet over red images, such an effect is to be expected if the red images represent the planet and the violet ones its enveloping shell. Measurements of the plates indicate the inequality to exist, but an exact determination of its value is difficult to make. Edge fading, or darkening at the limb of the red images, offers the most serious obstacles to a satisfactory comparison of sizes of photographs taken in the two colours, and in first calling attention to the inequality in diameter I ventured to suggest

that, in order to circumvent this difficulty, the diameter of the solid surface be determined by timed measurements of markings in the course of their diurnal travel across the disc. Such a method had not to the best of my knowledge been used for the determination of a planet's diameter, but Dr. Trumpler has since employed it in his observations of Mars, and has arrived at conclusions respecting the size of the solid ball that are in reasonable agreement with those based on direct measurements of the infra-red disc. His estimate of the excess in radius of yellow images over that of the solid surface is 52 miles, my own value of the excess, based on measurements of the diameters of violet and infra-red photographs, is 60 miles. My personal view is that the actual height of the atmosphere may be much greater or much less than these estimates indicate, but that observations of the kind will eventually prove useful in determining the extent of the Martian atmosphere.

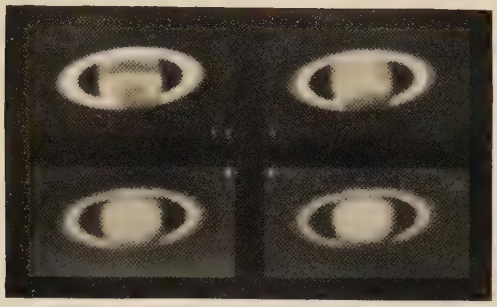
Venus.

The colour reactions of Venus are, superficially at least, the direct antithesis of those of Mars, for such structure as they present is found in the ultra-violet photographs and not in the ones taken with light of the red end of the spectrum. The former show dark bands and tree-like markings extending from the terminator.* Adopting the view that the ultra-violet images are pictures of the planet's outer atmosphere, the irregularities shown in them are assumed to be atmospheric. It is probable that these markings are of the same nature as those that have occasionally been seen upon the planet by observers with the telescope. Barnard recorded the impression that the telescopic features are not permanent, a fact that would be well explained by their atmospheric character. The uniformity of the red images indicates either that there are no surface markings on Venus, which in the light of our experience with other planets does not seem altogether likely, or that the atmosphere is not effectively penetrated even by deep red light. A series of photographs similar to those referred to here was made in 1927 by Dr. Ross at Mount Wilson; and Quénisset at Paris in 1921 (*C.R.*, **172**, 1645), using violet light alone, photographed markings whose impermanency suggested that they were atmospheric. The evidence at hand appears to indicate that the atmosphere of Venus is practically impenetrable to light of the visible spectrum, and that it is unhomogeneous at its outer surface.

Saturn.

Photographs of Saturn in different colours seem first to have been undertaken by Professor R. W. Wood in 1915 with the 60-inch reflector at Mount Wilson. I shall presently refer to an exceedingly interesting observation that he made on that occasion. The photographs shown in figs. 23 to 26 were taken at Mount Hamilton, and are partially

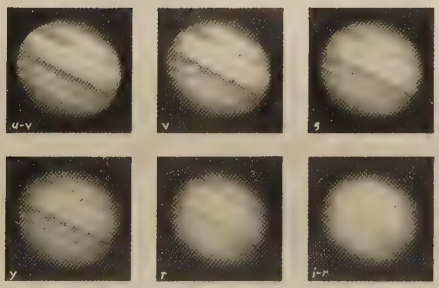
* The photographs are not illustrated in this paper.



Figs. 23-26.—Saturn, 1927 July 13, 14.

Saturn.

Fig. 27.—1915. Fig. 28.—1927.



Figs. 29-34.—Jupiter, 1927 Oct. 2.

representative of a complete colour series. They are of rather inferior quality, a fact which is to be attributed very largely to the low declination, and consequently unfavourable position for observation, of Saturn at the present time. The colours here given are ultra-violet, violet, orange, and red. An increase in strength of the trace of the crepe ring on the planet, with increase of wave-length, is apparent, and this suggests increase in opacity of that part of the ring system for the longer-waved colours. However, I believe judgment in respect to this matter should be withheld until photographs of better quality are obtained and subjected to photometric measurement. Darkening of the limb is pronounced in the long-wave colours, while a certain amount of limb light is seen in the ultra-violet photographs. The latter circumstance would seem to imply the presence of a layer of transparent atmosphere over what we may, in the emergency, call the " photosphere " of Saturn.

A wide dark belt, similar to that shown in the ultra-violet photograph, was found in violet and ultra-violet photographs by Wood in 1915. He tentatively proposed an explanation, which, however, he did not regard as the true one, namely, that the belt might be the trace upon the planet of an inward extension of the ring, composed of fine dust and not ordinarily visible. At the time of Wood's observation (1915) we were looking at the planet over the southern (or upper, in the photographs) surface of the ring, and he found the band north of the planet's equator. Since then the earth has crossed the plane of the ring, and we are now looking over the northern surface. It is a necessary consequence of Wood's hypothesis that the belt should now be south of the equator, that is to say, that it should have followed the shadow-casting segment of the ring from below to above the equator (in the photographs) and this is, in fact, found to be the case (see figs. 27 and 28). A further test of the hypothesis should be available in a few years when the rings are seen " edge on," at which time the belt, if it is a phenomenon of obscuration related to the ring system, should vanish, or at least become extremely narrow.

Jupiter.

The photographs of Jupiter shown in figs. 29 to 34 were taken in the colours ultra-violet, violet, green, yellow, red, and infra-red. The alterations are gradual from colour to colour, but a comparison of first and last images shows great differences. The progressive darkening of the limb, as the wave-length of the light used is increased, is well brought out. Limb darkening is commonly regarded as due to atmospheric absorption, and its almost complete absence from ultra-violet photographs suggests that these are representations of the planet's outermost atmospheric layers, or more strictly, that we do not see to the bottom of the atmosphere by light of that colour. The gradual fading of the red spot as the wave-length of the colour increases is very noticeable. The shadow of the second satellite is shown on the disc, and near it a fine double belt, the lower element of which fades

through the series. The seeing on the night on which these photographs were taken was the best had while the observations of Jupiter were in progress, and these photographs are, perhaps, the best obtained of the planet. I should like to say that the Crossley telescope was equal to the occasion provided by whatever deity presides over the seeing. Some idea of the definition of the photographs can be had from the fact that the shadow of the satellite which appears on the disc is less than a second in diameter, and the two narrow and well-separated belts near it are distant, centre to centre, about $1\frac{1}{4}$ seconds of arc.

While reflecting on the possible effects of absorption at different points of the disc it seemed not unlikely that cinematic photographs of Jupiter might be of service in detecting changes, occurring from moment to moment, that might escape detection in the usual course of observation.* The rotation period of Jupiter is approximately 10 hours, and by photographing through intervals of 4 or 5 hours it is possible to cover the complete rotation in three consecutive nights. Films thus secured have been pieced together for a complete revolution, and the whole repeated time and again. This results of course in the intermittent appearance of satellites, whose positions in the several sections of the film bear no relation to each other. These bodies appear from time to time, move over limited arcs of their orbits, and vanish. It will be understood that this is a first attempt in this direction and that better success may reasonably be anticipated in future efforts. I should like to state that the assembling of the films and their preparation for presentation was most generously undertaken by Dr. Kenneth Mees, a Fellow of this Society, and the Director of the Eastman Research Laboratory, whose kind co-operation through several years, in the preparation of special plates used in taking all of these photographs, I also acknowledge with the greatest pleasure. I wish also to record my indebtedness to Mr. F. C. Chappell, of the Lick Observatory, for assistance, and especially for making the lantern slides with which these remarks have been illustrated.

A Determination from Binary Star Data of the Giant and Dwarf Branches of the Russell Diagram. By R. O. Redman, B.A.

(*Communicated by Professor A. S. Eddington.*)

§ 1. Acting upon a suggestion made by Professor Eddington, an attempt has been made, as described below, to determine the central lines of the giant and dwarf branches of the Russell diagram by a method which largely eliminates the necessity for reference to parallax determinations. The necessary calculations were commenced under

* Illustration is, of course, impossible in the printed paper. The colours used in taking the cinema films were ultra-violet, blue, and infra-red.

the impression that nothing of the kind had been done before, but, when about half-way through, I discovered that Lundmark and Luyten had already done very similar work.* However, there is some difference of method, and also there is no determination of spread in the earlier paper, so it was thought worth while to complete the present investigation.

The general outlines of the Russell diagram indicate that for both giant and dwarf stars there is a relation between spectral type and absolute magnitude. Indeed, if one chooses a group of giants or of dwarfs of one particular type, their absolute magnitude will cluster closely about some mean value. Thus let the mean absolute magnitude of X type dwarfs be M_x and that of Y type dwarfs be M_y; then, if we take any two dwarf stars, one of type X and the other of type Y, the difference in their absolute magnitude will be $M_x - M_y + v$, where v is comparatively small and of the nature of an accidental error. Now, if we can observe the difference of absolute magnitude of a number of dwarf stars of different types, we can, by means of a least squares solution, find those relative values of the absolute magnitude corresponding to the various spectral types involved which will make Σv^2 a minimum; and, provided we have sufficient observational material, these relative magnitudes should yield a very fair approximation to the slope and shape of the "main series." Similar work may be done for giant stars.

In order to find the difference of absolute magnitude of two stars, one usually requires their parallaxes and apparent magnitudes, but should the two have the same parallax the required difference of absolute magnitude will be simply the difference of apparent magnitude, and the actual value of the parallax is not required. Examples of such stars are found in ordinary binary systems, in physical pairs (common proper motion and near positions in sky), and in star clusters. Using these, results have been obtained which agree very satisfactorily with those derived in other ways.

Lundmark and Luyten divided the main series into three sections, assumed that its central line was straight in each of these, and found the average slope of these lines from binary stars, etc.

§ 2. *Observational Material.*—An effort was made to use only reliable observational material, although this further restricted the very scanty amount available.

Binaries. Practically all double stars for which good determinations of the spectral types of both components have been made are to be found in a list given by Leonard.† This includes 238 stars. Of these, 73 have components of the same spectral type and are thus of no use for our work. We have further to exclude known spectroscopic binaries and white dwarfs. There remain 54 dwarfs and 60 giants, these being distinguished by the usual criterion that in a dwarf the fainter component is the redder. A few stars may get wrongly classified by this method, but they will be all of nearly the same type, with a small

* Lundmark and Luyten, *A.J.*, 828.
† *L.O.B.*, 343.

difference in absolute magnitude, and will make little difference to our results. One star (Polaris) is clearly a giant, with a dwarf companion, and so was omitted. A few binaries were included which have had their spectra determined since the publication of Leonard's list.

Physical pairs. For these reference was made to lists by Miss Cannon,* and Doig,† while search was made for stars with well-marked common proper motion in Boss's Catalogue, in Schorr's *Eigenbewegungs-Lexikon*, and other proper-motion lists. It was thought inadvisable to include stars unless the common proper motion was fairly large and well marked, because, although by including those whose motions were smaller and agreed less perfectly we should have gained in numbers, any such advantage would probably have been more than counterbalanced by the inclusion of a number of pairs without actual physical connection.

Cluster stars. Another possible source of observational data is the open clusters such as the Hyades, Pleiades, and the Præsepe cluster. The spectral types of a large number of stars in these groups have been determined. It happens, unfortunately, that most of these cannot be used. Bruggencate‡ has shown that there is absorption of light within these clusters, particularly in the Pleiades, to a less extent in Præsepe, and that there are indications of it in the Hyades also. This affects the apparent magnitude according to depth of the stars in the cluster and spoils them for our purpose. The effect appears to be small in the case of the Hyades, and we have included these, together with a few stars from h and χ Persei, in one solution.

Spectroscopic binaries, as far as they have been discovered, were also eliminated from the physical pairs and the cluster stars.

Finally we were left with Dwarfs: 62 binaries, 70 physical pairs, and 64 cluster stars; Giants: 60 binaries and 19 physical pairs. This appears to be all the trustworthy material available, and one has had to be content with it, such as it is, although one would wish for a much greater amount. It was hoped at first that the colour indices of stars, such as those given by Shajn, would be of use. Results obtained from these agreed in the main with our other results, but it appears that the accuracy of determination of spectral type from colour is not sufficient to make the use of these indices advisable, unless, indeed, a very large number of them were known, in which case their numbers might compensate for their inferior individual accuracy.

§ 3. *Method.*—The stars used are of all types from Bo to M5. It is impossible to obtain values of the relative magnitudes for all sub-types from so little raw material, so that actually the mean absolute magnitudes corresponding to Bo, B5, Ao, . . . Mo, M5 were taken as unknowns and labelled α, β, γ, δ, . . . μ. When a type such as F2 occurred its absolute magnitude was taken as $\frac{3}{5}\epsilon + \frac{2}{5}\zeta$, *i.e.* we interpolated linearly between the various half-types. This is a valid approximation provided there are no discontinuities or sudden irregularities in either branch of

* *H.A.*, **56**, No. 7.
† *M.N.*, **82**, 372.
‡ *B.A.N.*, 128.

the Russell diagram. As far as the " main series " is concerned this is fairly certainly true. The evidence is not so strong in the case of the giant branch, some investigators have found suggestions of discontinuities, but in the present state of our knowledge the above assumption appears quite legitimate.

We now consider giants and dwarfs quite separately. As remarked above, the difference of absolute magnitude of two stars of two given spectral types is equal to a certain fixed quantity, together with a comparatively small accidental deviation. Thus, for instance, if we find two stars of types F2, G5 and observed difference of magnitude 2·2, we can write

$$(\tfrac{3}{5}\epsilon + \tfrac{2}{5}\zeta) - \theta = 2{\cdot}2 + v.$$

Each of our pairs yields a similar equation. In the principal solution we had 132 such equations of condition for the dwarfs and 79 for the giants. The problem is to find a value of $\alpha, \beta, \gamma \ldots$ which will best fit these equations. We choose those which will make Σv^2 a minimum, and obtain them by forming and solving normal equations in the usual way. These normal equations, of which there is one for each of $\alpha, \beta, \gamma, \ldots$, are not independent. The unknowns always appear in the equations of condition as differences, and it is only as such that we can determine their values. If $\alpha, \beta, \gamma \ldots$ are eliminated one by one in a perfectly straightforward manner, we have a useful check in that the coefficients of each unknown add up to zero at each stage of the working.

The giant branch was assumed to meet the " main series " at Ao, and stars earlier than this were not considered in the giant solution, which otherwise proceeded exactly as for dwarfs.

§ 4. *Results.*—These were :

	$\mu-\alpha$.	$\mu-\beta$.	$\mu-\gamma$.	$\mu-\delta$.	$\mu-\epsilon$.	$\mu-\zeta$.	$\mu-\eta$.	$\mu-\theta$.	$\mu-\iota$	$\mu-\kappa$.	$\mu-\lambda$.
warfs	12·42	11·60	10·50	9·28	9·00	8·48	7·59	6·71	6·63	5·01	4·16
iants			−3·33	−3·16	−2·54	−2·17	−2·30	−1·53	−0·50	+0·54	+2·25

These give the slope and shape of the central lines of the two branches of the diagram. The absolute position was fixed by comparison with the mean magnitudes derived from the dynamical parallaxes of binary stars. These were given in a previous * paper, but need two corrections before using them here ; bolometric magnitudes must be reduced to visual magnitudes, and all known spectroscopic binaries must be excluded. In fitting the least squares result to these magnitudes greatest weight was given to the part of the " main series " between Ao and Ko, as in both cases this was the region with the greatest number of stars.

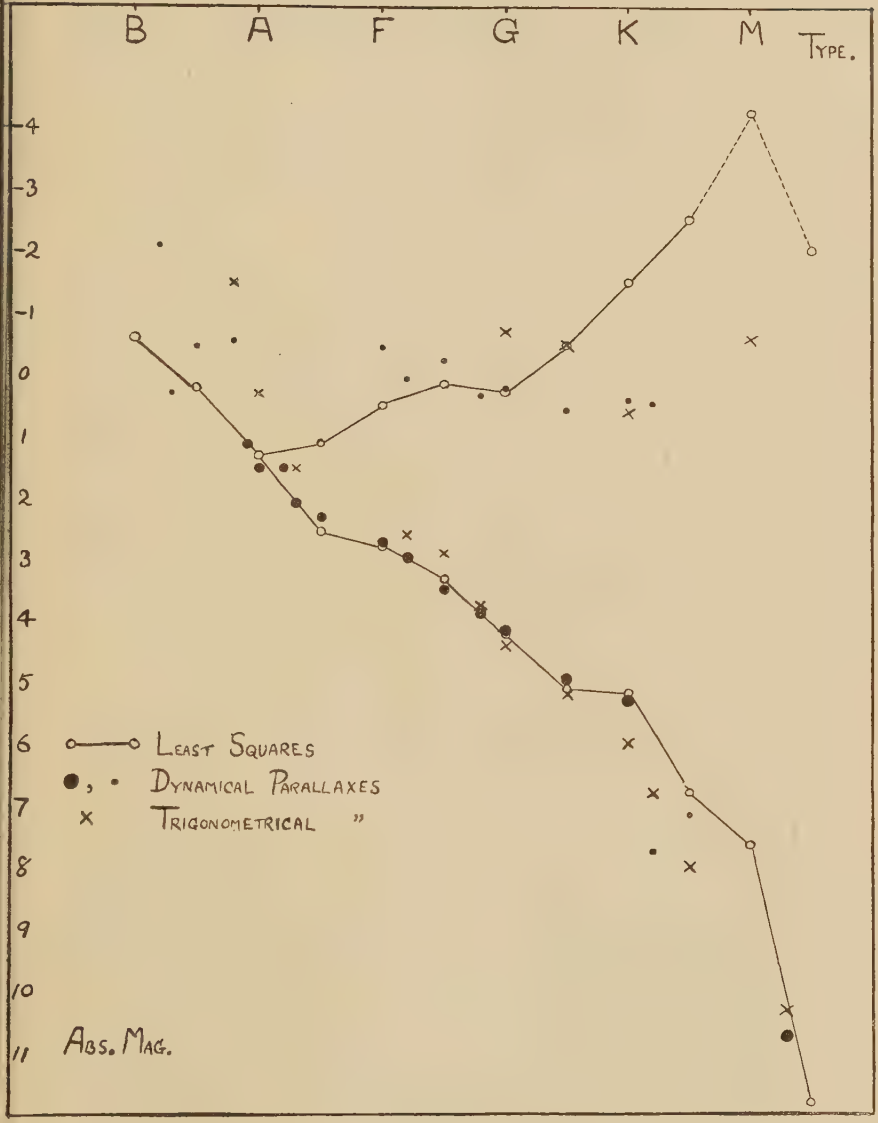
The adjoining table gives the various results. For further comparison we also give mean absolute magnitudes recently derived by Dr. Nassau from trigonometrical parallaxes.

* *M.N.* **88**, 45.

Type.	Dwarfs. Least Sqs. m	Dyn. Pllx. m	Trig. Pllx. m	Type.	Giants. Least Sqs. m	Dyn. Pllx. m	Trig. Pllx. m
Bo	−0·62		−2·3				
B2		(−2·11)					
B3		(+0·28)					
B5	+0·20	(−0·46)					
B8		(−0·58)	−1·5				
B9		+1·11					
Ao	1·30	1·55	+0·3	Ao	+1·30		
A2		1·55		A2			
A3		2·01	1·5	A3			
A5	2·52	2·32		A5	1·13		
Fo	2·80	2·75		Fo	0·51	(−0·46)	
F2		2·96	2·6	F2		(+0·05)	
F5	3·32	3·42	2·9	F5	0·15	(−0·24)	
F8		3·83	3·8	F8		(+0·31)	
Go	4·21	4·19	4·4	Go	0·28	(+0·24)	−0·7
G5	5·09	4·92	5·2	G5	−0·49	(+0·58)	−0·5
Ko	5·17	5·29	6·0	Ko	−1·53	(+0·40)	+0·6
K2		(7·74)	6·8	K2		(+0·43)	
K5	6·79	(7·15)	8·0	K5	−2·57		
Mo	7·64			Mo	−4·27		−0·9
M3 (b)		(10·77)	10·3	M3			
M5	11·80			M5	−2·03		

These figures were used in constructing the diagram in fig. 1. It will be seen that from Ao to Ko on the " main series " there is excellent agreement between the least squares solution and the dynamical parallax results. This is not altogether due to the " fitting " explained above, which can only be accomplished by moving the least squares points together up or down the diagram. Actually good agreement is to be expected, provided both methods of deduction are reliable, because an appreciable number of the stars used appear in both investigations. Otherwise, of course, the methods are entirely independent.

Some comment must be made on other parts of the figure where agreement does not appear to be so good. For instance, there is some discrepancy at both ends of the dwarf branch. This is largely explained by the fact that the corresponding dynamical parallax points are determined from a few stars only, and the majority of these are without determined orbits, so that the parallaxes are correct statistically but not individually. The mean magnitudes earlier than B9 and later than Ko, which are uncertain for this reason, are put in brackets in the table and in fig. 1 are indicated by smaller dots. An exception is the point for M3 (Mb), which was found from two stars with determined


B
A
F
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Type.
-4
-3
-2
-1
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5
6
7
8
9
10
11
Least Squares
Dynamical Parallaxes
Trigonometrical "
Abs. Mag.

Fig. 1.

orbits and should be fairly trustworthy. It is satisfactory to note that it agrees with the least squares solution. Of course one must not expect to find the latter to be so reliable at the ends of the branch as nearer the middle, where more stars are to be found. There is reasonable agreement with the trigonometrical points. The greatest differences are to be found in type B. Three reasons may be suggested for this : (*a*) the trigonometrical parallaxes are few for these stars, (*b*) they are also mostly small and thus even less reliable than usual, (*c*) there is reason to believe that the scatter in absolute magnitude of B stars is considerable. This last may in part be observational, due to the difficulty of accurate classification of this type of spectra, but will nevertheless affect all our results for these stars.

With regard to the giants, the least squares results differ considerably from those from both sets of parallaxes. Various explanations are again forthcoming. The eight dynamical parallax points are determined from less than fifty stars altogether, and are thus untrustworthy for reasons given above. Three giant stars with determined orbits yield points agreeing with the curve, viz. Capella, Go, $0^m{\cdot}0$; ϵ Hydrae, F8, $0^m{\cdot}4$; 20 Persei, Fo, $0^m{\cdot}6$. The trigonometrical parallaxes suffer from the fact that they are mostly small. On the other hand, in the least squares solution we may have included as giant pairs a few consisting of a red giant and an earlier dwarf. This would tend to make the slope of the giant branch too great. On investigation it seemed unlikely that any such doubles are in the list of " giant " binaries at any rate, and a solution using these alone, without the physical pairs, yields a practically identical slope as far as type K. The extreme end of the curve (beyond K6) depends on very few stars and is therefore not well defined.

Another solution for the dwarf branch, including the 64 cluster stars, was made, treating these as 32 independent binaries. The result was to all intents and purposes the same as that for binaries and physical pairs alone.

The agreement of the three binaries, whose orbits have been determined, with the giant result seems to indicate that our assumption that the branches join at Ao is fairly correct. It must be pointed out, however, that there is little other evidence to contradict an assumed junction at A5, for example, which would bring the whole set of giant points a magnitude lower. The slope which we have obtained for this branch appears tolerably reliable, and one is inclined to trust it rather than the parallax results where the two disagree.

§ 5. *Scatter.*—An attempt was made to estimate the amount of scatter in absolute magnitude of these stars. For comparison two other methods were used to find the scatter on the " main series."

(i) Scatter from the least squares solution.

The observed and calculated differences of magnitude in each pair were found, and the difference between these was divided equally between the two stars, *e.g.* we might have had Fo – Ko, observed difference of magnitude 2·7 and calculated 2·4, then a deviation of 0·15 was assigned to each of Fo and Ko. The stars were collected into

suitable groups and the spread found for each. As each deviation involves two stars we must multiply these average values by $\sqrt{2}$ in order to get the average deviation per star.

Dwarfs. Type.	-B5.	B6-A5.	A6-F5.	F6-G5.	G6-K5.	K6-.
No. of stars	12	59	32	76	56	29
Average deviation	$0^m.35$	$0^m.62$	$0^m.59$	$0^m.49$	$0^m.52$	$0^m.34$

Total average deviation $\pm 0^m.52$ (264 stars).

Giants. Type.	Ao-A5.	A6-F5.	F6-G5.	G6-K5.	K6-.
No. of stars	59	39	34	19	7
Average deviation	$0^m.36$	$0^m.34$	$0^m.36$	$0^m.36$	$0^m.38$

Total average deviation $\pm 0^m.36$ (158 stars).

In the case of the solution for dwarfs including cluster stars, the distribution of scatter among the various types was a little different, but the average for all stars was virtually the same, viz. $0^m.53$. The general uniformity of the scatter, which is particularly noticeable in the giants, is partly due to our method of dividing up the difference (observed − calculated) equally between the two stars concerned. This will level out any large residuals from individual components, but in the absence of other data this is unavoidable. The method of least squares also tends to smooth out the residuals. The averages for all stars together should be fairly reliable, the only occasion for surprise being that the giant scatter, contrary to expectation, is less than that for dwarfs. As giants and dwarfs have been treated in exactly the same way throughout, it appears probable that this result is real, although, of course, it may only hold for double stars or even only for the particular sample with which we have been working.

(ii) Scatter from dynamical parallaxes of binaries with determined orbits.

As pointed out recently by Russell,* the dynamical parallaxes of binary stars with determined orbits, especially those for which Eddington's mass-luminosity relation has been employed in estimating the mass of each system, are of considerable accuracy. Although Russell finds evidence for a small systematic error in the values I obtained in this way,† the absolute magnitudes derived from them should be good determinations, and in particular should yield good values for the spread we are investigating. The observed deviation from the mean of each type, averaged for all (72) stars on the "main series" from Fo to Ko, is $0^m.66$. (Only the principal component of each binary was used, and all spectroscopic binaries were eliminated.)

(iii) Scatter from dynamical parallaxes of binary stars without determined orbits.

For these the observed scatter S_0 is made up of two parts: the true scatter S_1 and an additional scatter S_2, due chiefly to the unknown inclinations of the orbits of these stars.

* *A.J.*, 897. † *M.N.*, **88**, 50.

We can evaluate S_2 theoretically, and, assuming an S_1, we can find the resultant scatter which best fits the observed S_0. For reasons which will be discussed below, the result is not likely to be so accurate as those from the two previous methods.

Consider a group of stars with true mean absolute magnitude M. We can take M = 0, *i.e.* measure magnitude from this mean. Let us do this, and, further, assume a Gaussian form for S_1, viz. that the probability of occurrence of a true magnitude m' to $m' + dm'$ is proportional to $e^{-h^2m'^2}dm'$.

Now, proceeding along the same lines as in the previous paper,* *i.e.* assuming the mass-luminosity relation to be $L \propto M^4$ and that the parallax is given by a formula of the type $\pi = \frac{A \operatorname{cosec} i_1}{M^{\frac{1}{3}}}$, we see that, for a star of true magnitude m', the probability of a calculated magnitude m to $m + dm$ will be proportional to $\frac{e^{-2\mu}}{\sqrt{(1 - e^{-2\mu})}}dm$, where $\mu = \frac{m - m'}{2{\cdot}60} + {\cdot}451$.

Thus the probability of observing a star of magnitude m to $m + dm$ will be

$$\int_{\text{all } m'} e^{-h^2m'^2} dm' \frac{e^{-2\mu}}{\sqrt{(1 - e^{-2\mu})}} dm \quad . \quad . \quad . \quad (1)$$

We evaluated this integral for various m, against which the results were plotted, giving the distribution of the m's as predicted by theory.

The integral (1) may be transformed a little, so that the probability is proportional to

$$dm \int_0^\infty e^{-h^2(m - 2{\cdot}60\mu + 1{\cdot}17)} \frac{e^{-2\mu}}{\sqrt{(1 - e^{-2\mu})}} d\mu.$$

The required numerical values were obtained by assuming a value for h, then drawing a graph for each m and counting squares.

Similar work was done for the case where the parallax is given by an expression of the form

$$\pi = \frac{B \operatorname{cosec}^{\frac{1}{2}} i_1 \operatorname{cosec}^{\frac{1}{2}} i_2}{M^{\frac{1}{3}}}.$$

Here we get a double integral, viz. the probability of an observed magnitude between m and $m + dm$ is proportional to

$$dm \int_{\text{all } m''} \frac{e^{-2\mu_2}}{\sqrt{(1 - e^{-2\mu_2})}} dm'' \int_{\text{all } m'} e^{-h^2m'^2} \frac{e^{-2\mu_1}}{\sqrt{(1 - e^{-2\mu_1})}} dm' \quad . \quad (2)$$

where

$$\mu_1 = (m'' - m' + {\cdot}295)/{\cdot}8686, \qquad \mu_2 = (m - m'' + {\cdot}672)/1{\cdot}737 \ .$$

An algebraic solution appeared impossible, so that graphical methods, although extremely laborious, were again used. Results were plotted against m, as before.

* *M.N.*, **88**, 42.

The two formulæ quoted above were the principal ones employed in evaluating the dynamical parallaxes, and if each was used to the same extent, the mean of the two curves derived from (1) and (2) (and reduced to the same scale) should give the final distribution as predicted by theory. It was found that the case $h = \cdot 7053$, corresponding to an average error $\eta = 0 \cdot 8$, gave the best agreement with observation (see fig. 2). The observed curve had to be displaced through a distance $m = 0 \cdot 5$ to make it fit the other; this was explained in the previous work, where a displacement $0^{m} \cdot 3$ was suggested. The extreme right-hand part of the observed curve is affected by the presence of giants, and this explains why it remains above the theoretical curve.

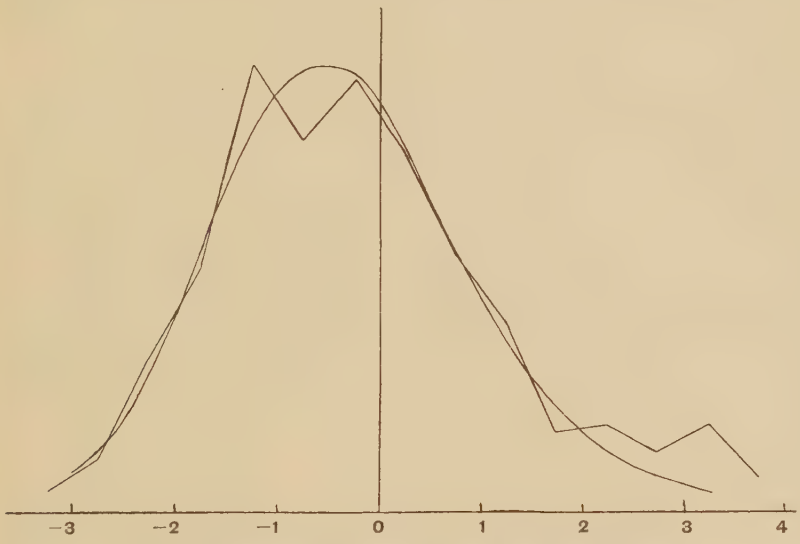

Fig. 2.—Comparison of Observed with Theoretical Spread.

Abscissæ: deviation from mean in magnitudes.
Ordinates: frequency.

At first it was thought possible to find the spread in this manner for different groups of stars. To this end three groups were taken, viz. Fo – F5, F8 – Go, G5 – Ko, and the observed frequency curves were found for each. These are given in fig. 3, where they have been reduced to approximately the same scale. Whereas the first group gives a curve like the theoretical form, the other two, particularly the last, are much less recognisable. The Fo – F5 group has a scatter roughly corresponding to $\eta = 0 \cdot 5$. Although no estimate was made for the other two groups, it is clear that the spread is greater for F8 – Go and still greater for G5 – Ko.

The value $\eta = 0 \cdot 8$, which we have derived by this method as the average spread for stars on the "main series," is probably not very accurate. Firstly, we have made a number of assumptions as to the

form of the true spread and also with reference to the formulæ used in deriving the parallaxes. These assumptions are not likely to be more than approximately true. Secondly, these stars have only been observed over small parts of their orbits, and many, in addition, are difficult pairs for which the probable error of observation is of the same order as the quantity measured. This will increase the apparent true scatter. Further, the method actually considers only the case of stars with equal components. However, we can conclude that the true scatter increases markedly as one goes down the " main series " and

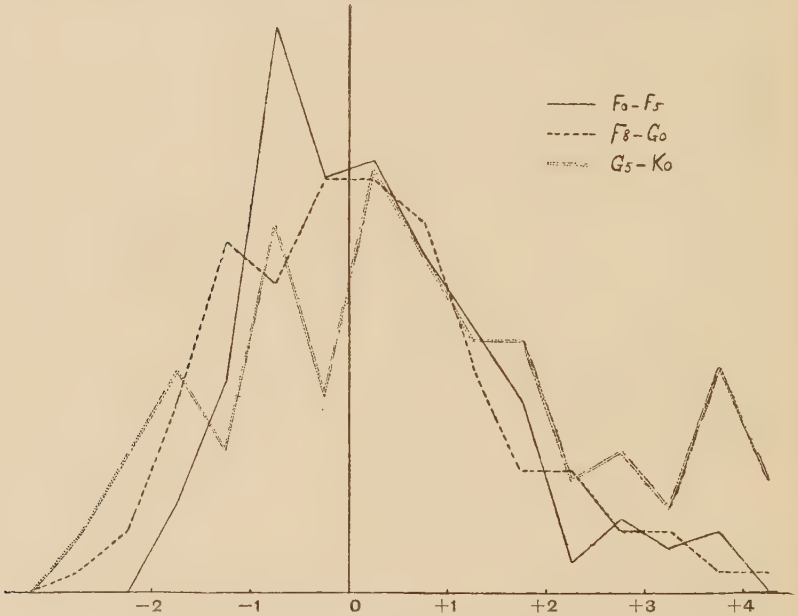

FIG. 3.—Scatter for three Groups of Stars on " Main Series."
Abscissæ : deviation from mean in magnitudes.
Ordinates : observed frequency.

that it is small in the region of Fo. The conclusion previously reached, that the mean magnitudes derived from dynamical parallaxes of stars without determined orbits require a correction of a few tenths of a magnitude, has been confirmed. It may be noted that the theoretical curve, derived as above, is not so unsymmetrical as was anticipated previously ; the true scatter, even when small, smooths out to an unexpectedly great extent the highly unsymmetrical scatter due to unknown inclination. The theoretical curve also suggests that the proportion of spurious " giants " (actually scattered dwarfs) is greater than was previously supposed, and this is probably the explanation of the large motions that were derived for these stars in the previous paper.

Our three estimates of the average scatter from the central line of the " main series " are :

(i) $\pm$ $0^m.52$ without using parallaxes.

(ii) $\pm$ $0^m.66$ from dynamical parallaxes of binaries with determined orbits.

(iii) $\pm$ $0^m.8$ from dynamical parallaxes of binaries without determined orbits.

The second of these is probably the nearest to the truth.

It is of interest to note that Dr. Nassau,* using trigonometrical parallaxes only, has recently estimated the " probable spread " on the " main series " to be about $0^m.5$, which corresponds to an average spread of about $\pm$ $0^m.6$. The chief point of disagreement lies in the fact that he finds the spread greatest for earlier stars, although he says this may possibly be due to the inclusion of giants.

§ 6. *Conclusion.*—The results for the determination of the central line of the dwarf branch of the Russell diagram are very satisfactory, although derived from a very small amount of data. The giant result is not so certain, although three reliable points from individual stars agree ; otherwise we have no good check. One is led to hope that the method will prove valuable when a larger number of spectral determinations become available.

The average spread from the centre line of the main series (Fo – Ko) is probably about $\pm$ two-thirds of a magnitude.

My thanks are due to Professor Eddington both for the initial suggestion which led to this work and for criticism and advice during its completion.

A Note on Dr. P. A. Taylor's Paper " The Equilibrium of the Calcium Chromosphere." By W. H. McCrea.

(*Communicated by R. H. Fowler, F.R.S.*)

1. In a very interesting paper † Dr. P. A. Taylor has recently given a modification of Prof. Milne's theory of the calcium chromosphere to take account of the sun's curvature and the variation of gravity with distance from its centre. His work, however, appears to be open to criticism on two grounds.

First, the Schuster-Schwarzschild approximation, when applied to a spherical atmosphere, leads to an inconsistency. It requires too high a density of radiation if the net flux is to be conserved. For, if there were no chromosphere at all, Taylor's work (*loc. cit.*, p. 609, § 6) gives, from the constancy of net flux, $I_\nu = (I_\nu)_0(a/r)^2$, where I_ν is the mean

* *M.N.*, **88**, 583.

† P. A. Taylor, *M.N.*, **87**, 605 (1927), where full references to Milne's papers will also be found.

intensity in $0 \leqslant \theta \leqslant \pi/2$. Therefore, the back radiation being now zero, the density of radiation is $2\pi I_\nu/c = 2\pi(I_\nu)_0(a/r)^2/c$. But, when the chromosphere is absent, the intensity is $(I_\nu)_0$ along any ray from the sun, giving for the actual density $(I_\nu)_0$ (solid angle subtended by sun)/c. For large r, this is equal to $\pi(a^2/r^2)(I_\nu)_0/c$, *i.e. one-half* Taylor's value. This can be remedied by averaging over $0 \leqslant \theta \leqslant \sin^{-1}(a/r)$ and $\sin^{-1}(a/r) \leqslant \theta \leqslant \pi$ instead of $0 \leqslant \theta \leqslant \pi/2$ and $\pi/2 \leqslant \theta \leqslant \pi$.

Second, the assumption of a constant T_0 leads to a chromosphere with a finite density at infinity. This appears inconsistent with the assumption that the back radiation tends to zero. We show that radiative equilibrium alone, and the assumption that the back radiation tends to zero, require that the *density must tend to zero* (for a non-zero net flux of any radiation which can be absorbed at all), so there must, presumably, be a temperature gradient, and we suggest below that it is reasonable to try T varying as $1/r^2$. It should be possible to derive the gradient from the properties of the gas.

The present note seeks to incorporate these ideas into a development otherwise analogous to Taylor's. Our equations can only be solved numerically and give values very close to certain of Taylor's, except for large r.

Unless the contrary is stated, the symbols below have exactly the same meanings as in Milne's and Taylor's papers, to which reference should be made. We have omitted, however, the suffix ν in the intensities, since they refer to the same frequency throughout.

2. We start with the equations of propagation of radiation and of radiative equilibrium used by Taylor, viz.:

$$\cos\theta\frac{\partial I^*}{\partial r} - \frac{\sin\theta}{r}\frac{\partial I^*}{\partial\theta} = \alpha n_2\frac{q_1}{q_2}(\sigma + I^*) - \alpha n_1 I^* \quad . \quad (1)$$

$$n_1\int_0^\pi I^* \sin\theta d\theta = n_2\frac{q_1}{q_2}\int_0^\pi (I_\nu{}^* + \sigma)\sin\theta d\theta \quad . \quad (2)$$

These possess the integral of the constancy of net flux

$$\int_0^\pi I^* \sin\theta\cos\theta d\theta = \frac{a^2 C}{2r^2} \quad . \quad . \quad . \quad (3)$$

where $4\pi^2 a^2 C\Delta\nu$ is the total outward net flux and the present C is $1/a^2$ of Taylor's.

Now multiply (1) by $\sin\theta d\theta$ and integrate with respect to θ between limits 0 and θ_r where

$$\theta_r = \sin^{-1}\frac{a}{r} \quad . \quad . \quad . \quad . \quad . \quad (4)$$

and is the semi-vertical angle of the tangent cone to the sun from a point distant r from its centre. The L.H.S. gives

$$\int_0^{\theta_r}\left[\sin\theta\cos\theta\frac{\partial I^*}{\partial r} - \frac{\sin^2\theta}{r}\frac{\partial I^*}{\partial\theta}\right]d\theta = \int_0^{\theta_r}\frac{\sin\theta\cos\theta}{r^2}\frac{\partial}{\partial r}(r^2 I^*)d\theta - \frac{a^2}{r^3}I^*(r,\theta_r) \quad (5)$$

since

$$\int_0^{\theta_r} \sin^2\theta \frac{\partial \mathrm{I}}{\partial\theta} d\theta = \frac{a^2}{r^2}\mathrm{I}^*(r, \theta_r) - 2\int_0^{\theta_r} \mathrm{I}^* \sin\theta\cos\theta d\theta.$$

But now

$$\frac{1}{r^2}\frac{\partial}{\partial r}\int_0^{\theta_r} r^2 \mathrm{I}^* \sin\theta\cos\theta d\theta = \int_0^{\theta_r} \frac{\sin\theta\cos\theta}{r^2}\frac{\partial}{\partial r}(r^2\mathrm{I}^*)d\theta$$

$$+ \mathrm{I}^*(r, \theta_r)\sin\theta_r\cos\theta_r\frac{\partial\theta_r}{\partial r} \quad \text{and} \quad \cos\theta_r\frac{\partial\theta_r}{\partial r} = -\frac{a}{r^2}. \qquad (6)$$

Therefore the expression (5) reduces to

$$\frac{1}{r^2}\frac{\partial}{\partial r}\int_0^{\theta_r} r^2\mathrm{I}^* \sin\theta\cos\theta d\theta.$$

Now replace I^* *in this range of* θ by its mean value I.
Using the results

$$\int_0^{\theta_r} \sin\theta\cos\theta d\theta = \frac{a^2}{2r^2}; \qquad \int_0^{\theta_r} \sin\theta d\theta = 1 - \sqrt{1 - \frac{a^2}{r^2}} \qquad (7)$$

the integrated form of (1) is

$$\frac{a^2}{2r^2}\frac{d\mathrm{I}}{dr} = \alpha\left[-n\mathrm{I} + \sigma n_2\frac{q_1}{q_2}\right]\left[1 - \sqrt{1 - \frac{a^2}{r^2}}\right] \qquad (8)$$

Similarly if I' is the mean of I^* for θ in (θ_r, π) we find

$$-\frac{a^2}{2r^2}\frac{d\mathrm{I}'}{dr} = \alpha\left[-n\mathrm{I}' + \sigma n_2\frac{q_1}{q^2}\right]\left[1 + \sqrt{1 - \frac{a^2}{r^2}}\right] \qquad (9)$$

This method of averaging replaces the Schuster-Schwarzschild approximation used by Milne and Taylor. It seems more natural to use this rather than the latter, when we have to consider large distances from the sun, and it does not lead to the inconsistency mentioned in § 1. Also it has the incidental advantage that $\mathrm{I}^*(r, \theta_r)$ cancels out without having to be estimated like $\mathrm{I}^*(r, \pi/2)$ in the previous work.

Using the average values in (2) it becomes

$$n\left[\mathrm{I}\left(1 - \sqrt{1 - \frac{a^2}{r^2}}\right) + \mathrm{I}'\left(1 + \sqrt{1 - \frac{a^2}{r^2}}\right)\right] = 2\sigma n_2\frac{q_1}{q_2}. \qquad (10)$$

The equations (8), (9), and (10) give the integral $\mathrm{I} - \mathrm{I}' = \mathrm{C}$, which is the averaged form of (3) and shows that our averaged equations *themselves* possess the integral of constant flux. This was also the case in the former work, but does not appear to have been pointed out.

(10) can now be written

$$\mathrm{I} + \mathrm{I}' - \mathrm{C}\sqrt{1 - \frac{a^2}{r^2}} = 2\sigma\frac{n_2}{n}\frac{q_1}{q_2}. \qquad (10')$$

We shall assume that $I' \to 0$ as $r \to \infty$. This seems necessarily true, since otherwise I′ would have to be finite throughout a finite solid angle at an infinite distance from the sun. Hence $I \to C$ as $r \to \infty$. The L.H.S. of (10′) thus tends to zero at infinity and so

$$\frac{n_2}{n} \to 0 \quad \text{as} \quad r \to \infty \quad . \quad . \quad . \quad . \quad (11)$$

and thus can only happen in a natural manner if, in addition,

$$\frac{d}{dr}\left(\frac{n_2}{n}\right) \to 0 \quad \text{as} \quad r \to \infty \quad . \quad . \quad . \quad (11')$$

Subtracting (9) from (8) and substituting for $(I + I')$ from (10′), we find

$$\sigma \frac{q_1}{q_2} \frac{d}{dr}\left(\frac{n_2}{n}\right) = -\alpha n C - \frac{C}{2} \frac{d}{dr}\sqrt{1 - \frac{a^2}{r^2}} \quad . \quad . \quad (12)$$

Taking account of (11′), this shows at once that we must have

$$n \to 0 \quad \text{as} \quad r \to \infty \quad . \quad . \quad . \quad . \quad (13)$$

if we are to have a non-zero C (since α cannot vanish for the frequency considered).

(11) and (13) are important conditions to be fulfilled by any permissible solution. Milne's violates (11) and Taylor's violates (13).

The foregoing results are independent of the means of support of the chromosphere and, in particular, of any assumption regarding its temperature.

3. Now, however, we have to bring in the equation of mechanical equilibrium which is, following Taylor and with him neglecting the gravitation of the chromosphere itself,

$$\frac{dp}{dr} = -(n_1 + n_2)\frac{mga^2}{r^2} + \frac{n\pi\alpha C \Delta\nu}{c}\frac{a^2}{r^2}.$$

This can be written

$$\frac{dp}{dr} = -mg\frac{a^2}{r^2}n\left[1 + \frac{n_2}{n}\left(1 + \frac{q_1}{q_2}\right) - \frac{\pi\alpha C\Delta\nu}{cmg}\right] . \quad . \quad (14)$$

If the chromosphere is " fully supported " the ratio of the pressure force to the gravitational force must tend to zero as $r \to \infty$. We must therefore have

$$\left[\frac{dp}{dr} \Big/ mg\frac{a^2}{r^2}(n_1 + n_2)\right] \to 0, \quad i.e. \left[\frac{dp}{dr} \Big/ mg\frac{a^2}{r^2}n\right] \to 0,$$

since $n_2/n \to 0$. Hence, in this case,

$$\frac{\pi\alpha C\Delta\nu}{cmg} = 1 \quad . \quad . \quad . \quad . \quad (15)$$

which is, of course, the result obtained by Milne * and Taylor.† It is again independent of the temperature.

Whether the chromosphere is fully supported or not, we obtain by differentiating (14) and using (12)

$$\frac{d}{dr}\left\{\frac{r^2}{n}\frac{dp}{dr}\right\} = \frac{mga^2}{\sigma}\mathrm{C}\left(1+\frac{q_2}{q_1}\right)\left\{n\alpha+\frac{1}{2}\frac{d}{dr}\sqrt{1-\frac{a^2}{r^2}}\right\} \quad . \quad (16)$$

We have

$$p = 2(n_1+n_2)k\mathrm{T}$$

or, with sufficient accuracy $= 2nk\mathrm{T}$ (see Taylor) . . (17)

where T is the temperature of mean motion of the ions and electrons at the point considered.

Now we have seen that n must tend to zero at large distances, and, owing to the form of (16) and the physical nature of the case, we expect it to do so in a simple manner, *e.g.* without a periodic term. It seems, therefore, that n should behave asymptotically like $r^s e^{-tr}$, where $t \geqslant 0$ and $s<0$ if $t = 0$. Further, we expect (16) to admit of a solution, the "fully supported" case, behaving asymptotically as an inverse power of r. It is easy to see that this is possible only if T behaves asymptotically like $r^{-(1+\epsilon)}$, where $\epsilon>0$.‡

We are thus led to try writing

$$\mathrm{T} = \mathrm{T}_0\frac{a^2}{r^2} \quad . \quad . \quad . \quad . \quad (18)$$

and to take $\mathrm{T}_0 = 6000°$ K corresponding to the outside of the photosphere.

Some considerations like these are necessary in order to have consistent assumptions. Taylor's work shows that assuming a constant temperature leads to an infinite chromosphere, which would seem to contradict the assumption that the back radiation from it tends to zero.

Equations (16) and (18) give

$$\frac{d^2}{dr^2}\log n + \frac{2}{r^2} = \mathrm{A}\left[n\alpha+\frac{1}{2}\frac{d}{dr}\sqrt{1-\frac{a^2}{r^2}}\right] \quad . \quad . \quad (19)$$

where

$$\mathrm{A} = \frac{mg\mathrm{C}(1+q_2/q_1)}{2\sigma k\mathrm{T}_0} = 1{\cdot}151\times 10^{-9}.$$

This gives n, and n_2/n can then be found using (14) and (18).

4. *Integration of the Equations.*—Our equations cannot be solved parametrically by the methods employed by Milne and Taylor. A numerical solution must suffice.

We shall look for the "fully supported" case.

* E. A. Milne, *M.N.*, **86**, 8 (1925), equation (1).
† Taylor (*loc. cit.*), equation (31).
‡ See § 6 of the present paper.

Our boundary conditions are then :

(i) as $r\to\infty$, $n\to 0$ in such a manner that, in addition [*cf.* (14)],

$$\frac{r^2}{n}\frac{dp}{dr}\to 0 \quad . \quad . \quad . \quad . \quad . \quad (20)$$

(ii) at $r = a$, I has the photospheric value $I_0 = \sigma/[\exp(h\nu/kT_0) - 1]$, *i.e.* from (10′), at $r = a$,

$$\frac{n_2}{n} = \frac{1}{2\sigma}\frac{q_2}{q_1}[2I_0 - C],$$

i.e. substituting this in (14) and using (18), at $r = a$,

$$\frac{1}{n}\frac{dn}{dr} - \frac{2}{r} = -0{\cdot}945\frac{mg(1 + q_2/q_1)}{2kT_0[\exp(h\nu/kT_0) - 1]}$$

since $C = 0{\cdot}11\ I_0$ the residual intensity; *i.e.* finally

$$\left[\frac{1}{n}\frac{dn}{dr}\right]_{r=a} = -9{\cdot}854\times 10^{-9} \quad . \quad . \quad . \quad (21)$$

It is easy to see what the asymptotic behaviour of the solution must be, for, if $n\to 0$ faster than $1/r^2$, the asymptotic form of (19) is

$$\frac{d^2}{dr^2}\log\frac{n}{r^2} = 0, \qquad i.e. \quad n = r^2e^{ar+b},$$

with $a < 0$ which is not allowed by (20).

If n does not $\to 0$ as fast as $1/r^2$ the asymptotic form is

$$\frac{d^2}{dr^2}\log n = A\alpha n,$$

when n behaves like $\sec^2\kappa(r - r_1)$, where κ is a constant, which is impossible.

If $n\to 0$ like $1/r^2$ there is a unique asymptotic solution,

$$n\alpha = 4/Ar^2, \text{ satisfying (20)} \quad . \quad . \quad . \quad (22)$$

This is evidently the solution we want, so we have to find by trial an initial value of n which gives a solution behaving like this as $r\to\infty$.*

We put $n\alpha = N$.

The difficulty in the numerical integration is the rapid variation of N at the beginning of the range of r. After various other attempts the following method proved fairly satisfactory :—

Write

$$N = N_1e^y \quad . \quad . \quad . \quad . \quad (23)$$

* It is clear, of course, that we cannot use this to integrate *in* from some large r, for it never gives the *exact* solution for a finite r. It does not, for example, distinguish between $1/r^2$ and $1/(r-r_0)^2$.

where N_1 satisfies

$$\frac{d^2}{dr^2}\log N_1 = AN_1 \text{ with } \frac{N_1'}{N_1} = -9{\cdot}854 \times 10^{-9} \text{ at } r = a.$$

This gives

$$N_1 = \frac{B}{2A}\operatorname{cosech}^2\left\{\frac{\sqrt{B}}{2}(r - r_0)\right\}. \quad . \quad . \quad (24)$$

with

$$2AN_1 + B = 9{\cdot}71 \times 10^{-17} \text{ at } r = a.$$

It is found necessary to take B positive, and various values have to be tried, r_0 being fixed by the value chosen.

The rapid variation of N goes into N_1, which can easily be evaluated.

Substituting (23) in (19) and reducing, we find that y must satisfy the equation

$$\frac{d^2y}{d\rho^2} = -\frac{2}{\rho^2} + a^2AN_1(e^y - 1) + \frac{40{\cdot}09}{\rho^2\sqrt{(\rho - 1)(\rho + 1)}} \quad . \quad (25)$$

where $\rho = r/a$. This is the equation to be integrated numerically with the conditions y, $y' = 0$ for $\rho = 1$. It has the advantage that the y' term is absent. To start the numerical work we make use of the fact that very near to $\rho = 1$ it is satisfied by $y = 37{\cdot}81\ (\rho - 1)^{3/2}$.

To get from $\rho = 1$ to $\rho = 1{\cdot}2$ fifteen intervals were taken, increasing from 0·0005 to 0·05.

To calculate n_2/n in this "fully supported" case, we see from (14), (18)

$$n_2/n = -\frac{2kT_0}{mg(1 + q_1/q_2)}\frac{d}{dr}\log\left(\frac{n}{r^2}\right) \quad . \quad . \quad (26)$$

This reduces to

$$n_2/n = K\left[a\sqrt{B}\coth\frac{\sqrt{B}}{2}(r - r_0) + \frac{2}{\rho} - y'\right] \quad . \quad (27)$$

where

$$K = 2kT_0/mga(1 + q_1/q_2) = 9{\cdot}813 \times 10^{-6}.$$

5. *Numerical Results.*—The process of trying a series of values for B showed finally that it must lie between $1{\cdot}2 \times 10^{-18}$ and $1{\cdot}3 \times 10^{-18}$ ($B^{(1)}$ and $B^{(2)}$ say). Even these limits do not carry us very far, but they give a fair idea of the behaviour of n, n_2/n in the important range $\rho = 1$ to 1·2. It is quite laborious work getting these limits, and a great deal more would be required to find nearer ones.

The values of N_1 corresponding to $B^{(1)}$, $B^{(2)}$ respectively are found to be

$$\left.\begin{aligned} N_1^{(1)} &= \frac{5{\cdot}214 \times 10^{-10}}{\sinh^2\{38{\cdot}16(\rho - 1 + 0{\cdot}00293)\}} \\ \text{and} \\ N_1^{(2)} &= \frac{5{\cdot}648 \times 10^{-10}}{\sinh^2\{39{\cdot}72(\rho - 1 + 0{\cdot}00293)\}} \end{aligned}\right\} \quad . \quad . \quad (28)$$

The corresponding values of y are small for very small values of $(\rho - 1)$, and so it will be noticed that in both cases N then behaves like

$(r - r_0)^{-2}$ where $(1 - r_0/a) = 0{\cdot}00293$. It is interesting to note that the same is true in Milne's and Taylor's formulæ, where their $(1 - r_0/a)$ have values 0·00263 and 0·00242 respectively.

The asymptotic solution (22) is not very useful for numerical work since it appears that other powers of $1/r$ will be important up to some-

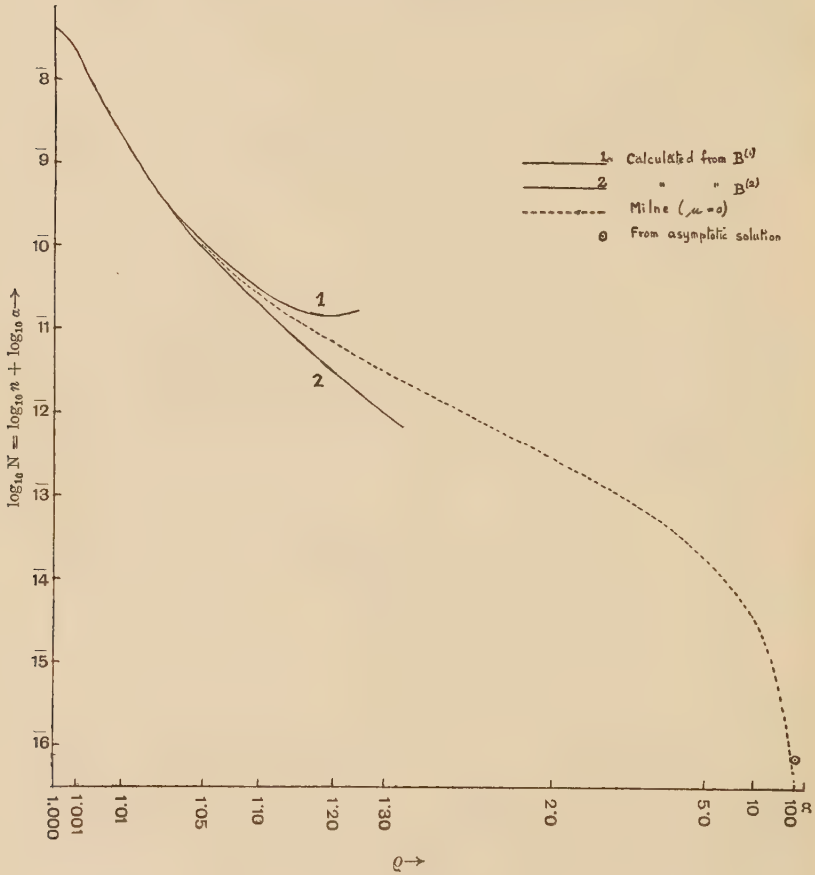

FIG. 1.

thing like $\rho = 50$. It does, however, give an idea of the difference between the present work and previous results for large r.

In Table I. are given the values of $\log_{10} N$ for $B^{(1)}$ and $B^{(2)}$ compared with those calculated from Milne's formula (quoted by Taylor,* eq. (13)),

$$N = \frac{2{\cdot}984 \times 10^{-13}}{(\rho - 1 + 0{\cdot}00263)^2} \quad . \quad . \quad . \quad (29)$$

* P. A. Taylor, *M.N.*, **87**, 616 (1927).

The value from the asymptotic solution is inserted for $\rho = 100$ and compared also with Taylor's value for $\mu' = 0$.

In Table II. are given the corresponding values of $\log_{10}(n_2/n)$ compared now with Taylor's value for $\mu' = 0$. These values are chosen for comparison as being on the whole the nearest to our values of the various results discussed by Taylor.* The others can easily be compared by referring to his diagrams.

Following Taylor's method we have plotted these values against $\sec^{-1}\rho$ in figs. 1 and 2 respectively.

Taking into account the values given for $\rho = 100$, it will be seen

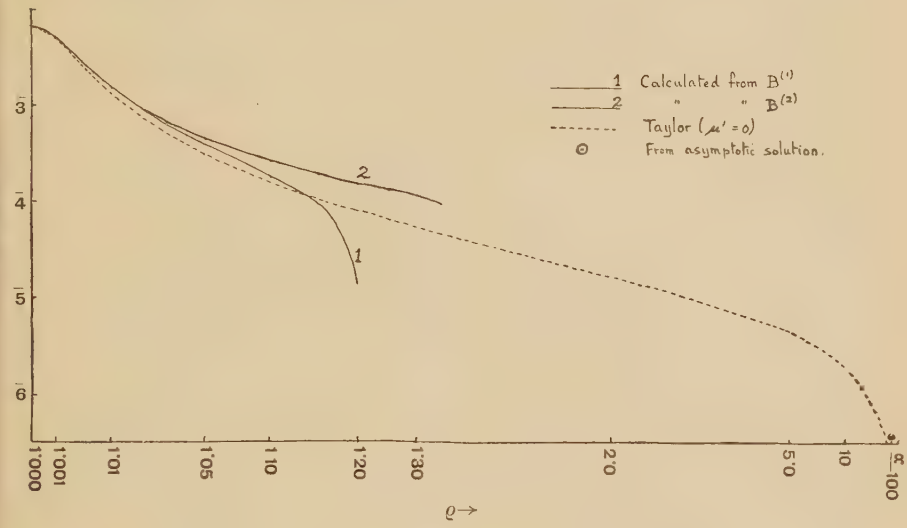

FIG. 2.

that the accurate solution of our equation must lie fairly near to those with which they are compared. Some additional support is lent to these calculations by the fact that Taylor found the best results for the light intensity † with Milne's law for n and his own with $\mu' = 10^{-4}$ for n_2/n rather than with his own law, with $\mu' = 0$, for these two quantities, which has the n finite at infinity. This would show that the observed intensities could be accounted for by a "fully supported" chromosphere.

We have left out of consideration the possibility of further ionisation. All we have been attempting is a slightly more complete and consistent account of the restricted problem.

* Except $\log_{10} N$ for $\mu' = 0$, $\varrho = 100$ which is inserted to show the difference from our asymptotic solution.

† P. A. Taylor, *M.N.*, **87**, 616 (1927).

TABLE I.*

ρ.	$\log_{10}$ N. Calc. from $B^{(1)}$.	$\log_{10}$ N. Calc. from $B^{(2)}$.	$\log_{10}$ N. Calc. from Milne (Eq. (29) above).
1·0000	$\bar{8}$·6198	$\bar{8}$·6025	$\bar{8}$·6348
1·0005	$\bar{8}$·4816	$\bar{8}$·4823	
1·0010	$\bar{8}$·3623	$\bar{8}$·3630	$\bar{8}$·3550
1·0015	$\bar{8}$·2584	$\bar{8}$·2579	
1·002	$\bar{8}$·1655	$\bar{8}$·1644	
1·004	$\bar{9}$·8677	$\bar{9}$·8672	
1·006	$\bar{9}$·6455	$\bar{9}$·6442	
1·008	$\bar{9}$·4603	$\bar{9}$·4661	
1·01	$\bar{9}$·3208	$\bar{9}$·3172	$\bar{9}$·2720
1·02	$\bar{10}$·8121	$\bar{10}$·8031	
1·03	$\bar{10}$·4887	$\bar{10}$·4765	
1·04	$\bar{10}$·2498	$\bar{10}$·1979	
1·05	$\bar{10}$·0520	$\bar{10}$·0125	$\bar{10}$·0324
1·10	$\bar{11}$·4969	$\bar{11}$·3298	$\bar{11}$·4522
1·15	$\bar{11}$·2434	$\bar{12}$·8656	
1·20	$\bar{11}$·1695	$\bar{12}$·5181	$\bar{12}$·8612
1·25	$\bar{11}$·2417	$\bar{12}$·2401	
1·30		$\bar{12}$·0099	$\bar{12}$·5130
1·35		$\bar{13}$·8101	
2·0			$\bar{13}$·4724
5·0			$\bar{14}$·2700
10·0			$\bar{15}$·5662
100·0	$\bar{17}$·8614 (Asymp. solution)	$\bar{13}$·4847 (Taylor $\mu' = 0$)	$\bar{17}$·4836

TABLE II.

ρ.	$\log_{10}(n_2/n)$. Calc. from $B^{(1)}$.	$\log_{10}(n_2/n)$. Calc. from $B^{(2)}$.	$\log_{10}(n_2/n)$. Calc. from Taylor ($\mu' = 0$).
1·0000	$\bar{3}$·8167	$\bar{3}$·8302	$\bar{3}$·8287
1·0005	$\bar{3}$·7579	$\bar{3}$·7614	
1·0010	$\bar{3}$·6988	$\bar{3}$·7025	$\bar{3}$·6785
1·0015	$\bar{3}$·6473	$\bar{3}$·6507	
1·002	$\bar{3}$·6016	$\bar{3}$·6049	
1·004	$\bar{3}$·4552	$\bar{3}$·4594	
1·006	$\bar{3}$·3471	$\bar{3}$·3516	
1·008	$\bar{3}$·2613	$\bar{3}$·2667	
1·01	$\bar{3}$·1899	$\bar{3}$·2037	$\bar{3}$·1184

* N is given rather than n since it enters more naturally and is independent of the estimate of the width of the absorption line.

The slight initial excess of the third column over the second must be spurious and the last figure meaningless.

TABLE II.—*continued.*

ρ.	$\text{Log}_{10}(n_2/n)$. Calc. from $B^{(1)}$.	$\text{Log}_{10}(n_2/n)$. Calc. from $B^{(2)}$.	$\text{Log}_{10}(n_2/n)$. Calc. from Taylor ($\mu' = 0$).
1·02	$\bar{4}$·9494	$\bar{4}$·9621	
1·03	$\bar{4}$·7995	$\bar{4}$·8200	
1·04	$\bar{4}$·6881	$\bar{4}$·7211	
1·05	$\bar{4}$·5993	$\bar{4}$·6471	$\bar{4}$·4930
1·10	$\bar{4}$·2521	$\bar{4}$·4163	$\bar{4}$·2021
1·15	$\bar{5}$·9093	$\bar{4}$·2860	
1·20	$\bar{5}$·1532	$\bar{4}$·1924	$\bar{5}$·9063
1·25		$\bar{4}$·1157	
1·30		$\bar{4}$·0468	$\bar{5}$·7319
1·35		$\bar{5}$·9830	
2·0			$\bar{5}$·2114
5·0			$\bar{6}$·6102
10·0			$\bar{6}$·2582
100·0	$\bar{7}$·5939 (Asymp. solution)		$\bar{7}$·2169

6. *The Temperature Distribution Law.*—It may be useful to attempt to give a slightly more general discussion.

Using (17), equation (16) takes the asymptotic form

$$\frac{d}{dr}\left\{\frac{r^2}{n}\frac{d(n\mathrm{T})}{dr}\right\} = \mathrm{P}n + \frac{\mathrm{Q}}{r^3}, \qquad \mathrm{P},\ \mathrm{Q} > 0 \quad . \quad . \quad (30)$$

and we have seen reason to think that n behaves asymptotically like $r^s e^{-tr}$.

(i) Suppose $n \to 0$ like r^{-u}, that is, $t = 0$, $s = -u$.

Then, from (30),

$$\frac{d}{dr}\left\{r^{2+u}\frac{d}{dr}(\mathrm{T}r^{-u})\right\} \sim \text{const. } r^{-u'}, \qquad u' = \min(u, 3),$$

therefore

$$\mathrm{T} \sim \text{const. } r^{-v},$$

where

$$v > 0,$$

but, from (14), the quantity in { } must $\to 0$ or const., therefore

$$v \geqslant 1 (> 1 \text{ in "fully supported" case}).$$

(ii) Suppose $n \to 0$ like $r^s e^{-tr}$, $(t \neq 0)$.

Then (30) will behave asymptotically like

$$\frac{d}{dr}\left\{\frac{r^2}{n}\frac{d(n\mathrm{T})}{dr}\right\} = \frac{\mathrm{Q}}{r^3}$$

giving

$$\left\{\frac{r^2}{n}\frac{d(n\mathrm{T})}{dr}\right\} = -\frac{\mathrm{Q}}{2r^2} - \mathrm{R}, \qquad \mathrm{R} \geqslant 0.$$

The form of this equation shows that T cannot contain an exponential factor. So, if it behaves asymptotically like r^{-v}, we find that when $t \neq 0$,

$$(\alpha) \text{ if } R = 0, \qquad v = 4.$$

This is the "fully supported" case, since the expression in $\{\ \}\to R \Rightarrow 0$, and

$$(\beta) \text{ if } R \neq 0, \qquad v = 2.$$

If, then, these elementary considerations are sufficient, it appears that, for large r, T must behave like r^{-v} with $1 \leqslant v \leqslant 4$.

We cannot attempt to discuss here how an atmosphere with its temperature tending to zero can merge into Eddington's diffuse matter in space with a temperature of about 10,000°. But it seems clear that this temperature cannot impose any boundary condition on the temperature of a stellar atmosphere. In fact, Eddington remarks * that he does not think there is any difficulty in the fact that the effective temperatures of some stars are lower than this. Also, presumably, the earth's atmosphere, for instance, possesses a low temperature at great heights.

7. The writer wishes to express his thanks to Mr. R. H. Fowler, F.R.S., for opportunities of discussing the work with him, and to Dr. D. R. Hartree, without whose advice the numerical integration could not have been performed.†

Trinity College, Cambridge :
1928 *June.*

The Distribution of Brightness in the Solar Corona of 1927 *June* 29. (Preliminary Note.)

By J. Balanovsky and E. Perepelkin.

(*Communicated by Professor A. Belopolsky.*)

§ 1. The expedition of the Pulkovo Observatory, consisting of six members, had chosen for the observation of the eclipse a site in the neighbourhood of Malmberget, North Sweden, whose geographic coordinates are as follows :—

$$\phi = 67^\circ\ 10'{\cdot}7 \text{ N.}$$
$$\lambda = 1^h\ 22^m\ 46^s{\cdot}2 \text{ East of Greenwich.}$$
$$h = +\ 490 \text{ m.}$$

The programme of the expedition included the study of the distribution of brightness in the solar corona. For this purpose the expedition was equipped with two instruments: a 4-inch Cooke triplet of 4 m. focal length and a short-focus camera with a 120 mm. Tessar object-glass by Zeiss, of 60 cm. focal length. The first instrument was operated

* Eddington, *Internal Constitution of the Stars,* p. 377.

† The method is similar to one described by Dr. Hartree in *Proc. Camb. Phil. Soc.*, **24**, 89 (1928), § 9.

by Mr. E. Perepelkin, with the assistance of Mr. V. Messer, instrument-maker of the Pulkovo Observatory; the second one by Mr. I. Balanovsky. The 4-inch lens, whose aperture was reduced to 2 inches by means of a diaphragm, was designed for the study of the prominences, the inner and middle corona. This instrument was mounted firmly upon wooden boxes; the Sun's image was received from a 6-inch heliostat. The second instrument, fixed on an equatorial mounting of Repsold and clock-driven, was designed for securing an image of the outer corona.

During June the weather in Malmberget was cloudy and rainy, but some days before the eclipse it became better; on the night and early morning of the 29th the sky was completely clear. When the eclipse began there was very little cloud, but nearly 10 minutes before totality thin transparent clouds began to cover the Sun; during the beginning of totality nearly all the north-east part of the solar corona was covered with clouds, which were followed by a comparatively large clear gap. The clouds moved fast towards north-east, and 10^s after the beginning of totality $\frac{3}{4}$ of the corona became quite clear; 20^s before the end of totality all the inner and middle corona was projected upon clear sky. Only after totality the clouds completely screened the Sun, but towards the end of the eclipse the sky again became completely clear.

During the $38^s{\cdot}5$ of totality six photographs were taken; four with the long-focus camera with exposures of 1^s, 4^s, 6^s, and 2^s respectively, and two with the short-focus camera with exposures of 1 and 3 seconds. All plates were developed on the day after the eclipse; the first three photographs obtained with the Cooke triplet, and those taken with the Zeiss Tessar, were made on Ilford Rapid Chromatic (backed) plates, the 2^s photograph on Ilford Process (backed).

Taking into account the corrections to the Moon's co-ordinates found by E. Perepelkin from observations of the partial phases of this eclipse, the times of the beginning and end of totality for the place of observation were: *

Beginning, $5^h\ 46^m\ 20^s$, G.C.T.
End, $5^h\ 46^m\ 58^s{\cdot}5$, G.C.T.

Below are given the times of the middle of exposures for the different photographs and the differences of equatorial co-ordinates of the Moon's and Sun's centres on the plate expressed in mm.

			s	h m s		
Cooke triplet,	Rapid Chromatic	No. 1 C.	Exp. 1	5 46 23	$\Delta x = -0{\cdot}16$	$\Delta y = -0{\cdot}02$
„	„	No. 2 C.	4	32	− ·07	− ·01
„	„	No. 3 C.	6	44	+ ·05	·00
	Process	No. 4 C.	2	54	+ ·15	+ ·02
Zeiss Tessar,	Rapid Chromatic	No. 1 Z.	1	23	− ·02	·00
„	„	No. 2 Z.	3	39	·00	·00

All photographs secured with both instruments are sharp and show many details.

* *Astr. Nachr.*, **232**, 132, 1928.

Brief Description of the Photographs.

No. 1 C. The plate is somewhat fogged, probably due to some light having fallen accidentally upon the plate. $\frac{3}{4}$ of the Sun is covered with clouds.
No. 2 C. $\frac{1}{4}$ of the corona covered with clouds.
No. 3 C. No clouds. The plate has some defects.
No. 4 C. No clouds.
No. 1 Z. $\frac{3}{4}$ of the corona covered with clouds. Sky fog.
No. 2 Z. $\frac{1}{4}$ of the corona in clouds. Dense sky fog.

For photometric purposes only the plates 2 C., 3 C., 4 C., 2 Z. were used.

§ 2. The following method of photographic photometry was adopted. A plate of 18 × 24 cm. was cut into three parts of size 13 × 18, 9 × 11, and 9 × 11 cm. respectively. The plate 13 × 18 was used for the photograph of the corona, the remaining parts served for the scales of densities recorded by means of a tube-photometer, before and after the eclipse, at Pulkovo.

The tube-photometer manufactured by Mr. V. Messer at Pulkovo consists of 18 tubes 7 cm. long, with a series of diaphragms placed within them. Both the ends of every tube are shut with plates provided with holes. The diameters of the holes on the plates directed to the sensitive film are of 0·8 mm.; those at the other end turned to the light source vary from 5·2 mm. to 0·7 mm. Such a photometer gives 18 variations of density, corresponding to brightness from 0·0 mg. to 4·3, at intervals of about 0·25 mg.

The density scale was obtained in two ways: either by using light from a 100-candle-power lamp which had passed through a series of ground and opal glasses, or by photographing the blue sky near the zenith. All photographs before the eclipse were obtained only by means of the lamp on chromatic plates with exposures of 25^s and on process plates with exposures of 300^s. On the photographs taken after the eclipse the density scale was obtained twice: by means of the lamp as stated above, and by exposing the photometer to the light of the blue sky near the zenith soon after sunset. In the latter case the exposure was kept the same as for the coronal photographs on the corresponding plate. These photographs of the density scales were developed immediately after exposing and were found to be fairly transparent and well defined. The laboratory photographs as well as the solar ones were developed during 7^m with a 4 per cent. solution of rodinal in distilled water at 19°·5 C. The fixing was made with a 30 per cent. solution of hyposulphite also in distilled water.

The chief sources of errors in the method described are:

(1) The non-simultaneity of exposing and developing the laboratory and eclipse photographs.

(2) The non-equality of exposure times.

(3) The difference in colour of the light sources.

Certainly in the reduction of all the material, the influence of the

fog, caused by scattered sky light in the neighbourhood of the corona, must be taken into account.

These systematic errors were studied in the laboratory and their influence accounted for in the definitive result. This question is treated in detail in § 4.

§ 3. The photometric measures of the plates were made with a Hartmann microphotometer. The photographs of the corona were measured along the Moon's radii ; two settings of the wedge were made at every point.* The distances from the edge of the Moon were reduced to those of the Sun's edge by means of Δx and Δy, given above.

The plates 2 C., 3 C., and 2 Z. were measured along 24 radii, separated from each other by 15°, the plate 4 C. along 72 radii, separated from each other by 5°, the angles being reckoned from the north. The plates 2 C., 3 C., and 4 C. were measured along each radius at intervals of 0·5, 1, 2 or 3 mm., dependent on the rapidity of decrease of brightness in the corona ; the plate 2 Z. at intervals of 0·25, 0·5, or 1 mm. Besides the measurements of the corona itself photometric estimations were made of the fog at points lying on the same radius, but either on the Moon's disc itself or beyond the limits of the corona on the plate. The conversion of the microphotometer readings into densities was made on the basis of a careful study of the wedge, carried through with a Martens' densitometer. The differences between the density of the corona and the fog were used further for the computation of brightness. The numerical value of the density of the fog was determined on the assumption of the law of linear change with distance along each radius. The change of the density of the fog does not exceed 0·01 on the plates made with the Cooke triplet, while on the plate 2 Z. the difference between the density of fog on the lunar disc and beyond the corona reaches + 0·2. Special plates with a density scale were measured in the same way before and after the measurements of the plates with the corona.

§ 4. The conversion of densities into stellar magnitudes was made in a graphical way. As fundamental graphs, the curves drawn on the basis of the measurement of the laboratory plates served. The agreement between the curves obtained before and after the eclipse is very close. The mean divergence between them does not exceed ± 0·1 mg. on the whole interval of the tube-photometer. Hence the conclusion may be drawn, that the influence of the non-simultaneity of exposing and developing of the laboratory and coronal photographs does not affect the results appreciably. The dependence of the variation of density with exposure time was specially studied in the laboratory,

* The plate 2 Z. was first measured by the method used by Bergstrand (*Études sur la distribution de la lumière dans la couronne solaire*, Stockholm, 1919, p. 14). This method consists in a prior setting of the wedge, and looking for places in the corona of the same apparent density as that of the wedge. But it was found that between these two methods there was a considerable difference when the densities were great. The cause of this difference is not yet explained. But as the investigation of the wedge and the measurement of the density scale were done by the method described below, it was natural to adopt it also for the measurement of the corona.

using plates taken from the same box. Small systematic differences were found, which were taken into account. In this way the fundamental curves were reduced to the corresponding exposure times of the corona. The differences between the characteristic curves obtained when the tube-photometer was illuminated by the light of the lamp and diffuse sky light proved to be greater. In the first case the curves showed a higher variation, while the differences between the curves on the whole interval reached 0·4 mg., in good agreement on all the plates; the effective wave-length of the corona lying between those of the lamp and the blue sky, a mean value of the two curves obtained was adopted. After all these reductions, definitive characteristic curves were drawn, which served for the conversion of the measured densities into stellar magnitudes. The uniformity of the emulsion and of the conditions of chemical treatment are characterised by the following numbers showing the change of density for one stellar magnitude, taken from the rectilinear part of the curve.

For plates No. 2 C., 0·612
No. 3 C., 0·622 } Rapid Chromatic.
No. 2 Z., 0·602

The plate No. 4 C. (Process) gives a similar value 0·643.

As already mentioned in § 3, the fog on the plates 2 C., 3 C., and 4 C. is very insignificant and is nearly of the same density as the chemical fog on the laboratory plates. Thus its influence is quite excluded by the simple subtraction of the densities. But for the plate 2 Z., where the fog was very considerable, such a procedure was certainly not sufficient. To study this question a series of special photographs on plates from the same box was taken in the laboratory. On every plate the scale of the tube-photometer was recorded twice, without * and with fog, produced by later exposure to scattered light. The measurement of the plates showed that with the limits of density of fog between 0·0 and 1·85 the dependence between the characteristic curves without fog and with fog, σ_0, may be represented by the formula :

$$\log I_0 = \phi(\sigma_0) \log I + \psi(\sigma_0), \quad . \quad . \quad . \quad (1)$$

where

I = brightness, corresponding to the measured density on the plate free from fog.

I_0 = brightness, corresponding to the same density on a plate with fog σ_0.

$\phi(\sigma_0)$ and $\psi(\sigma_0)$ are two functions whose numerical values are computed by the formulæ :

$$\left.\begin{aligned} \phi(\sigma_0) &= 0{\cdot}964 - 0{\cdot}075\sigma_0 \\ \psi(\sigma_0) &= 0{\cdot}013 - 0{\cdot}515\sigma_0 \end{aligned}\right\} \quad . \quad . \quad . \quad (1')$$

* The expression "without fog" is to be understood in the sense of the absence of fog obtained by simultaneous or later illumination with diffuse light. In fact, the plate is affected by chemical fog of insignificant density.

On the basis of the equations (1) and (1′) a characteristic curve was drawn for the density of fog on the plate 2 Z., which served for the determination of the brightness of the corona.

§ 5. The values of brightness of the corona, expressed in stellar magnitudes taken from the characteristic curves according to density, were plotted for every radius separately. The individual points fall on smooth curves with satisfactory accuracy.

Further mean curves were formed for the four quadrants limited by the position angles 0°, 90°, 180°, and 270°. As the position angle of the rotation axis of the Sun was only − 4°, the heliographic latitude of the Sun's centre being + 2°·5, the mean curves of decrease of the brightness of the corona can with but little error be related to the heliographic latitudes. The mean curve of brightness for the whole corona can be found by taking the mean from all curves for the different heliographic latitudes. Such a method of reduction diminishes the influence upon the mean curve of different local defects on the plate and gaps in numerical values of the brightness due to the clouds. Such a procedure is justified by the comparatively great symmetry of the corona with respect to the rotation axis of the Sun and the solar equator. The comparison of the plates 2 C. and 3 C. in the region free from clouds on the first plate and limited by position angles 105° and 285° allowed us to find the constant difference of the zero points, which served to reduce the plates to a common system. The disagreement between them does not exceed 0·2 mg. The photograph 4 C., although taken on a plate of another emulsion, could be combined with accuracy to 0·1 mg. with the two other plates 2 C. and 3 C., for two reasons :

(1) The disagreement between the plates is less than the accidental error allowed.

(2) Careful photometric investigations by Ludendorff, made in 1923, showed that the distribution of energy in the coronal spectrum does not depend upon the distance from the edge of the Sun's disc; in other words, the law of decrease of brightness in the corona is equal for rays of different wave-length.*

Below is given a table showing the distribution of brightness, in terms of stellar magnitudes within the corona, for different heliographic latitudes. The distances from the Sun's edge are given in millimetres on the plates—1 mm.= 51″·76.

* H. Ludendorff, *Spektralphotometrische Untersuchungen über die Sonnenkorona*, Berlin Preus. Akad. der Wissenschaften, Sitzungsberichte Phys.-Math. Klasse, 1925, 106. The conclusion of Ludendorff is based on the study of the coronal spectrum in the region 382 -498 $\mu\mu$. The effective wave-lengths of the corona for the chromatic and process plates are comprised within these limits.

[Table

Table I.

ϕ \ m	0·0	0·5	1·0	1·5	2·0	2·5	3·0	3·5	4·0	4·5	5·0	5·5	6·0	6·5
°														
0	1·0	1·5	2·3	3·1	4·2	5·5	6·8	8·2	9·6	11·2	12·8	14·5	16·9	20·4
15	1·4	1·8	2·5	3·3	4·3	5·2	6·4	7·7	9·2	11·0	12·8	14·8	17·4	19·0
30	0·7	1·2	1·6	2·1	2·8	3·8	5·1	6·6	8·2	10·1	12·1	14·7	17·9	21·2
45	0·3	1·0	1·6	2·2	3·1	4·3	5·6	7·1	8·6	10·4	12·2	14·4	17·0	21·0
60	0·4	0·8	1·4	2·1	2·9	4·0	5·3	7·0	8·8	10·7	12·6	14·9	17·6	19·6
75	0·2	0·5	1·0	1·6	2·3	3·2	4·3	5·6	7·0	8·5	10·4	12·7	15·4	17·9
90	0·2	0·6	1·0	1·6	2·4	3·3	4·4	5·6	7·0	8·5	10·0	12·0	14·8	18·4
Mean	0·60	1·06	1·63	2·29	3·14	4·19	5·41	6·83	8·34	10·06	11·84	14·00	16·71	19·64

The last line contains the mean values for the whole corona. If the distances h from the edge of the solar disc are expressed in parts of the radius, the observed brightness m, in stellar magnitudes, may be represented in the form

$$m = 5{\cdot}71 + 7{\cdot}5 \log (h + 0{\cdot}146) \quad . \quad . \quad . \quad (2)$$

Table II. contains the observed and computed values m_o and m_c for different distances h. The probable error of one value of m averages $\pm$ 0·05 mg.

Table II.

h.	m_o.	m_c.	$m_o - m_c$.	h.	m_o.	m_c.	$m_o - m_c$.
	mg.	mg.	mg.		mg.	mg.	mg.
0·033	0·00	+0·11	−0·11	0·375	3·50	3·59	−0·09
·058	0·50	0·53	− ·03	·457	4·00	4·06	− ·06
·089	1·00	0·99	+ ·01	·552	4·50	4·54	− ·04
·126	1·50	1·47	+ ·03	·649	5·00	4·96	+ ·04
·172	2·00	1·98	+ ·02	·768	5·50	5·42	+ ·08
·230	2·50	2·52	− ·02	0·917	6·00	5·91	+ ·09
·297	3·00	3·06	− ·06	1·077	6·50	6·37	+ ·13

Thus the decrease of intensity i in the corona may be represented with great accuracy by the relation

$$i = \frac{i_0}{(h + 0{\cdot}146)^3} \quad . \quad . \quad . \quad . \quad (2')$$

for h comprised between 0·03 and 1·08 radii of the Sun.

The isophotæ, drawn through 0·5 mg. (see fig. 1), are of great interest. The inner corona extends along the diameter with the position angle 75°–255°. The middle part of the corona is more or less symmetrical with respect to the solar disc. The outer isophotæ allow us to find the beginning of the long and thin rays, well seen on plate 2 Z. It is interesting to note that the innermost isophotæ are somewhat stretched to the Sun's edge in the neighbourhood of six prominences in position angles 54°, 72°, 140°, 255°, 318°, and 343°, *i.e.* in half of

all the cases. This phenomenon is most distinctly seen near the prominences with position angles 140° and 318°. For a detailed study of this phenomenon the corona was carefully remeasured at many points near the first of these prominences. On the basis of this material the isophotæ shown on fig. 2 were drawn. On the plates 2 C. and 4 C. the corona in the neighbourhood of this prominence shows a series of

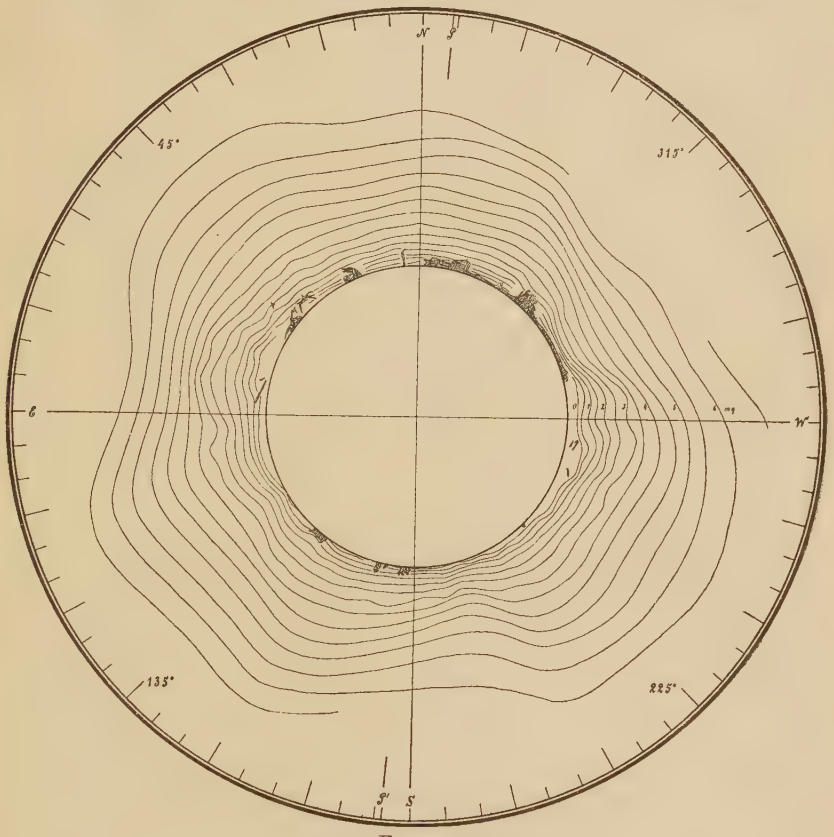

FIG. 1.

bright and dark nearly concentric arches. These arches may be drawn also on the basis of the isophotæ, joining consecutively their maxima and minima. The described phenomenon looks as if the coronal matter were attracted by the prominences. The reduction of the plate 2 Z. allowed the construction of the following table, showing the distribution of brightness in the outer corona. The distances from the Sun's edge are expressed in millimetres on the plate—1 mm. = 336″·5. Table III. gives the measurement of the part of the corona free from clouds; p is the position angle.

To combine the plate 2 Z. with the former ones, a region in four quadrants was chosen, comprised between the heliographic latitudes 0° and ± 45°. After taking into account the zero-point difference, the disagreement did not exceed 0·2 mg. The stellar magnitudes in Table III. are given in the system of the other plates. Combining together all the four measured plates, the distribution of brightness within the corona (in the limits of h between 0·05 and 3·12) in the region between

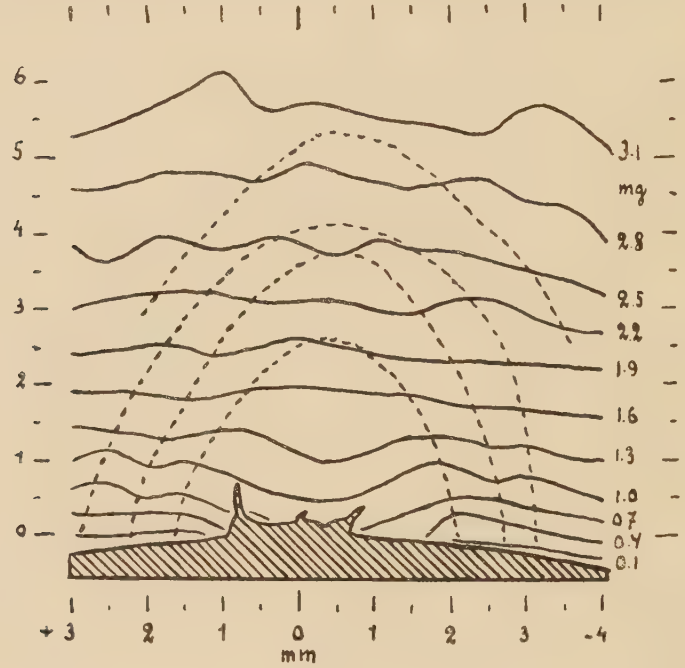

Fig. 2.

0° and 45° of heliographic latitude is represented best by the following formula, embracing the interval of nine stellar magnitudes:

$$m = 5{\cdot}63 + 6{\cdot}80 \log (h + 0{\cdot}100) \quad . \quad . \quad . \quad (3)$$

or in intensities:

$$i = \frac{i_0}{(h + 0{\cdot}100)^{2{\cdot}7}} \quad . \quad . \quad . \quad . \quad (3')$$

If the exponent be adopted as 3·0 the law of decrease of brightness is represented by the formula

$$m' = 5{\cdot}41 + 7{\cdot}5 \log (h + 0{\cdot}151) \quad . \quad . \quad (4)$$

or

$$i' = \frac{i_0'}{(h + 0{\cdot}151)^3} \quad . \quad . \quad . \quad . \quad (4')$$

TABLE III.

p / m	5·0	5·5	6·0	6·5	7·0	7·5	8·0	8·5	9·0
°									
30	4·45	5·00	5·60	..	..	..	..	..	..
45	4·50	4·97	5·60	6·18	6·82	..	..	..	..
60	4·47	5·05	5·56	6·14	6·80	7·43	8·05	8·63	9·60
75	4·58	4·94	5·32	5·83	6·62	7·60	8·15	9·00	..
90	4·55	4·95	5·43	6·00	6·85	7·80	8·70	9·90	12·30
105	4·45	4·93	6·02	6·53	6·97	7·70	8·52	9·15	9·95
120	4·40	4·72	5·45	6·12	6·83	7·75	8·40	8·95	9·80
135	4·60	4·83	5·43	6·05	6·92	7·70	8·60	..	..
150	4·90	5·31	5·78	6·32	7·10	7·68	8·35	9·20	..
165	4·58	5·15	5·65	6·30	7·00	8·00	9·50	..	..
180	4·02	4·58	5·18	5·84	6·58	7·35	8·20	9·25	11·00
195	4·15	4·50	4·98	5·60	6·40	7·32	..	..	..
210	4·47	4·88	5·35	5·87	6·50	7·45	8·60	..	..
225	4·90	5·42	5·98	6·58	7·30	8·22	..	..	..
240	4·65	5·40	6·08	6·80	7·80	8·75	9·90	11·00	12·30
255	4·95	5·45	6·05	6·82	7·65	8·60	10·15	11·40	12·80
270	5·00	5·42	6·00	6·50	7·32	8·10	8·80	..	..
285	4·15	4·95	5·60	6·25	7·40	..	..	..	..
300	..	4·45	5·18	6·00	6·65	..	..	..	..
315	..	4·30	4·97	5·80	6·45	7·75	..	..	..
330	4·55	4·98	5·45	5·92	6·50	..	..	..	..
345	4·30	4·80	5·28	5·80	..	..	..	..	..

In Table IV. the comparison is given of the observed values of brightness of the corona with those computed by formulæ (3) and (4). The probable errors for a single m are ± 0·07 mg. and ± 0·11 mg. respectively.

TABLE IV.

$h.$	$m_o.$	$m_c.$	$m_{c'}.$	$m_o-m_c.$	$m_o-m_{c'}.$	$h.$	$m_o.$	$m_c.$	$m_{c'}.$	$m_o-m_c.$	$m_o-m_{c'}.$
	m	m	m	m	m		m	m	m	m	m
0·047	0·0	−0·03	+0·14	+0·03	−0·14	0·666	5·0	4·85	4·75	+0·15	+0·25
·076	0·5	+0·50	+0·58	·00	− ·08	0·792	5·5	5·29	5·22	+ ·21	+ ·28
·110	1·0	1·02	1·03	− ·02	− ·03	0·976	6·0	5·84	5·80	+ ·16	+ ·20
·147	1·5	1·50	1·47	·00	+ ·03	1·178	6·5	6·35	6·34	+ ·15	+ ·16
·197	2·0	2·05	1·97	− ·05	+ ·03	1·514	7·0	7·04	7·07	− ·04	− ·07
·258	2·5	2·60	2·50	− ·10	·00	1·855	7·5	7·61	7·68	− ·11	− ·18
·326	3·0	3·11	3·00	− ·11	·00	2·192	8·0	7·99	8·18	+ ·01	− ·18
·406	3·5	3·62	3·50	− ·12	·00	2·595	8·5	8·55	8·70	− ·05	− ·20
·488	4·0	4·05	3·95	− ·05	+ ·05	3·115	9·0	9·08	9·26	− ·08	− ·26
·585	4·5	4·52	4·41	− ·02	+ ·09						

It is seen that the law of inverse proportionality with the square of distance from the Sun's edge, as deduced for instance from the study of the 1917 and 1925 coronas, is not confirmed by the above results.*

§ 6. *Summary.*—(1) The present paper contains the results of the measurement of the distribution of brightness within the solar corona of 1927 June 29 as photographed by the expedition of the Pulkovo Observatory at Malmberget (Lapland) with a 4-metre coronagraph and a Zeiss camera. A series of fair photographs were obtained in a gap between clouds.

(2) Four plates were measured for the study of distribution of the brightness in the corona. To form an absolute scale the following method was used. A plate of size 18 × 24 cm. was cut into three parts ; the corona was photographed upon one part, the two remaining parts served for the density scale, obtained before and after the eclipse by means of a tube-photometer. All plates were developed under the same conditions. The possible systematic errors were carefully studied in the laboratory and accounted for.

(3) The plates were measured on a Hartmann microphotometer, with a well-studied wedge.

(4) Characteristic curves, obtained by means of the tube-photometer reduced to the same conditions as during the eclipse, were used for conversion of density into brightness.

(5) The results of single plates were combined with sufficient accuracy. The isophotæ shown on fig. 1 contain interesting details in the proximity of the prominences. The law of decrease of brightness for different combinations of the plates was studied. The change of brightness with the distance h from the edge of the Sun is represented by formula (4′).

* Bergstrand, *loc. cit.*, and Harvard College Observatory Circ. Nr. 312.

Pulkovo Observatory :
1928 *May* 17.

Errata.

P. 604, line 7 (Velocity m.p.s.), *for* 15 *read* 18.
Pp. 668, 669, *for* Baxandall *read* Baxendell.
P. 668, footnote, *for* *M.N.R.A.S.*, **81**, *read* **71**.
P. 707, *Addendum :* The epoch of osculation for the elements of the orbit of Comet 1925 *c* (Orkisz) is 1925 Oct. 20·0 U.T.

LIST OF ADDITIONS

TO THE LIBRARY

OF THE SOCIETY

1927 JUNE 30 TO 1928 JUNE 30.

Serial Publications received in the regular course, and Reprints of Papers published in some of these Serials, are not included in this Annual List.

An asterisk (*) indicates that the work is an excerpt.

Acta Astronomica:
Series C. Vol. 1, pp. 17–20.
(*Cracow Observatory.*) 8vo. Cracow, 1928

Allegheny Observatory:
Publications. Vol. 6, Nos. 8, 9; Vol. 7, No. 1.
(*Observatory.*) 4to. Lancaster, Pa., 1927

Bacon (Gertrude):
Memories of Land and Sky.
(*Author.*) 8vo. London, 1928

Barnard (E. E.)
——: A Photographic Atlas of Selected Regions of the Milky Way. Edited by E. B. Frost and Mary R. Calvert. In two parts.
(*Editors.*) 2 vols. folio. Washington, 1927
Part 1. Photographs and Descriptions.
Part 2. Charts and Tables.

——: * Catalogue of 349 Dark Objects in the Sky. [Carnegie Inst. Publication No. 247.]
(*Carnegie Institution.*) 4to. Chicago, 1927

Bauschinger (Julius):
Die Bahnbestimmung der Himmelskörper. Zweite Auflage.
(*Author.*) Cr. 8vo. Leipzig, 1928

Berlin, Preussische Akademie der Wissenschaften:
Geschichte des Fixsternhimmels. Abteilung I., Bd. 6, 7.
(*Purchased.*) 4to. Karlsruhe, 1927
Band 6. 5^h Rektaszension.
Band 7. 6^h Rektaszension.

Blue Hill Meteorological Observatory:
Observations and Investigations made . . . in the year 1927, under the direction of Alexander McAdie.
(*Observatory.*) 4to. Cambridge, Mass., 1928

Bordeaux, Observatoire:
Carte photographique du Ciel. Zones +12°, +14°, +16° (30 charts).
(*Observatory.*)

Bosanquet (E. F.):
Leonard Digges and his Books.
(*Author.*) 4to. [Oxford], 1926

Bowie (William):
Isostasy.
(*Author.*) 8vo. New York, 1927

Brahe (Tycho):
Tychonis Brahe Dani Opera Omnia: edidit J. L. E. Dreyer. Tomi 9, 13.
(*Executors of the late Dr. Dreyer.*) 4to. Hauniæ, 1927–28

Breslau, Sternwarte:
* Veröffentlichungen, No. 4.
(*Observatory.*) 4to. Kiel, 1927

Campbell (Lewis) and William Garnett:
The Life of James Clerk Maxwell, with Selections from his Correspondence and Occasional Writings. New edition, abridged and revised.
(*D. Carder-Davies.*) 8vo. London, 1884

Canada, Geodetic Survey:
——: Annual Report of the Superintendent . . . for the fiscal year ending March 31, 1926.
(*Superintendent.*) 8vo. Ottawa, 1927
——: Publications. No. 11.
(*Department of the Interior.*) 8vo. Ottawa, 1928
No. 11. W. M. Tobey, Geodesy.

Cape of Good Hope, Royal Observatory:
——: Annals. Vol. 13, pt. 2.
(*Observatory.*) 4to. London, 1927
Vol. 13, Part 2. Results of Meridian Observations made . . . . in the years 1918–1925.

Cape of Good Hope, Royal Observatory—*continued:*
——: Cape Astrographic Zones. Vol. 11, Co-ordinates −51°.
(*Observatory.*) 4to. London, 1926

Cartuja (Granada), Observatorio:
Recuerdo del xxv Aniversario, 1902–1927.
(*Observatory.*) Fol. Granada, 1927

Catania, Reale Observatorio Astrofisico:
——: Annuario, 1927.
(*G. Favaro.*) 8vo. Catania, 1926
——: Catalogo Astrofotografico, 1900–0. Zona . . . fra le declinazioni +40° e +55°. Vol. 1, pt. 1 (fasc. 1); Vol. 2, pt. 2; Vol. 3, pt. 2 (fasc. 18); Vol. 4, pt. 2 (fasc. 26); Vol. 5, pt. 2 (fasc. 34).
(*Observatory.*) 4to. Catania, 1926–27

Cohn (B.):
Die Vorausberechnung der Sichtbarkeit der neuen Mondsichel.
(*Author.*) 8vo. Frankfurt a. M., 1927

Collard (Aug.):
Le Centenaire de la Création de l'Observatoire Royal de Bruxelles (1826–1926).
(*Author.*) 8vo. Bruxelles [1926]

Colombo Observatory:
Report on the Colombo Observatory, with Maps and Statistics, for the years 1920–1926.
(*Director.*) Fol. Colombo, 1921–27

Doig (Peter):
An Outline of Stellar Astronomy.
(*Author.*) 8vo. London, 1927

Esnault-Pelterie (R.):
——: Apparatus and Methods for Measurement of the Hertzian Hardness.
(*Author.*) 4to. London, 1927
——: L'Exploration par fusées de la très haute atmosphère.
(*Author.*) 8vo. Paris, 1928

Firenze, Osservatorio Ximeniano dei PP. Scolopi:
Riassunto delle Segnalazioni sismiche avute nell' anno 1927 nel Gabinetto Sismologico "Filippo Cecchi."
(*Observatory.*) Fol. typescript, 1927

Flammarion (Camille):
Annuaire astronomique et météorologique pour 1928.
(*Mme. Flammarion.*) 8vo. Paris, [1927]

Fotheringham (D. R.):
The Date of Easter and other Christian Festivals.
(*Author.*) 8vo. London, 1928

Gadomski (J.):
——: * Z. Herculis (=Her. 9).
(*Cracow Observatory.*) 8vo. Cracow, 1927
——: * Z. Vulpeculæ (=Vul. 9).
(*Cracow Observatory.*) 8vo. Cracow, 1927

Geneva, Observatoire:
*Publications. Astronomie, fasc. 1.
(*Observatory.*) 8vo. Genève, 1928

Geneva, Société Astronomique Flammarion de Genève:
Bulletin, No. 1 (1re Année), 1928.
(*Society.*) 8vo. Genève, 1928

Genoa, Istituto Idrografico della Regia Marina:
Lavori Geodetici compiuti in Italia e Colonie dal 1922 al 1926.
(*Institute.*) 8vo. Genova, 1927

Greenwich, Royal Observatory:
Determinations of Effective Wave-lengths of Stars made . . . in the years 1920 to 1925, under the direction of Sir Frank Dyson.
(*Observatory.*) 4to. London, 1926

Hagen (J. G.):
A Preparatory Catalogue for a Durchmusterung of Nebulæ. The Zone Catalogue. Third Instalment. Zones 80° to 110° N.P.D. (Specola Vaticana, Pubblicazioni, Vol. 10, pt. 3).
(*Specola Vaticana.*) 4to. Edinburgh, 1927

Hagen (J. G.) and M. Esch:
Atlas Stellarum Variabilium. Series Septima. Eas supplens Stellas Variabiles quæ ad Seriem VIm accesserunt. [Catalogue and Charts.]
(*Specola Vaticana.*) 4to. Friburgi, Brisgoviæ, and Leipzig, 1927

Hagihara (Yusuke):
*A Preliminary Study on the Stability of a certain Satellite-system.
(*Author.*) 4to. Tokyo, 1927

Handbuch der Astrophysik: Herausgegeben von G. Eberhard, A. Kohlschütter, H. Ludendorff. Band VI.
(*Purchased.*) 8vo. Berlin, 1928
Band VI. Das Sternsystem. Zweiter Teil. Bearbeitet von F. C. Henroteau, H. Ludendorff, K. Malmquist, F. Stratton.

Hasimoto (Masao):
*On the Transit Velocity of Radio Wave along Geodetic Line.
(*Tokyo Observatory.*) 4to. Tokyo, 1926

Helsingfors, Baltische Geodätische Kommission:
Comptes-Rendus de la deuxième séance de la Commission Géodésique Baltique réunie à Stockholm du 10 au 14 Août, 1926. Rédigés par le Secrétaire-Général Ilmari Bonsdorff.
(*Baltic Geodetic Commission.*) 8vo. Helsinki, 1927

Helsingfors, Observatoire:
Catalogue Photographique du Ciel. Tome I., fasc. 3, $0^h\ 30^m$ à 3^h.
(*Observatory.*) 4to. Helsingfors, 1927

Die Himmelswelt: Mitteilungen der Vereinigung von Freunden der Astronomie und kosmischen Physik. Jahrgang 37, Heft 9, 12.
(*Publishers.*) 8vo. Berlin, 1927

Hirayama (K.):
*On the stability of the retrograde planetary motion.
(*Author.*) 4to. Tokyo, 1927

Hirayama (K.) and K. Akiyama:
*Improved elements of the orbits of asteroids.
(*Authors.*) 4to. Tokyo, 1927

Holmgren (Rolf):
Internationale Erdmessung. Ein Beitrag zur preussischdeutschen Völkerrechtsgeschichte.
(*Preussiches Geodätisches Institut.*) 8vo. Potsdam, 1927

Hopf (Eberhard):
Zum Problem des Strahlungsgleichgewichts in den äusseren Schichten der Sterne. Strenge Lösung der singulären Integralgleichung von Milne.
(*Berlin Rechen-Institut.*) 8vo. Berlin, 1928

Hyderabad, Nizamiah Observatory:
Astrographic Catalogue 1900–0, Vol. 6, Dec. $-22°$.
(*Observatory.*) 4to. Edinburgh, 1927

Idelson (N.):
*Die Æquinoktialkorrektion des Pulkowoer Katalogs 1915·0.
(*Author.*) 4to. [Leningrad], [1927]

Jeans (J. H.):
Astronomy and Cosmogony.
(*Author.*) Cr. 8vo. Cambridge, 1928

Johannesburg, Union Observatory:
Southern Double Star Catalogue. R.A. 7^h–15^h $59^m.4$; 20^h–23^h $58^m.6$.
(*Observatory.*) Fol. typed sheets, 1927

Kimura (H.):
*Provisional Result of the Work of the International Latitude Service in the North Parallel +39° 8′ during the years 1925, 1926, 1927.
(*Author.*) 4to. Mizusawa, 1927–28

Kopff (A.):
Die Revision des Neuen Fundamentalkatalogs von Auwers.
(*Berlin Rechen-Institut.*) 8vo. Kasan, 1927

Kriloff (A. N.):
——: Lectures on the determination of comets' and planets' orbits from a small amount of observations.
(*Author.*) 4to. St. Petersburg, 1911
——: Sur la variation des éléments des orbites elliptiques des planètes.
(*Author.*) 4to. Petrograd, 1915
See also **Newton (Isaac).**

La Plata, Observatorio Astronómico de la Universidad:
——: Contribuciones Geofísicas. Tomo I, No. 3; Tomo II, No. 1.
(*Observatory.*) 4to. La Plata, 1927
——: Publicaciones. Tomo VI, Entrega 4; Tomo XI, No. 1.
(*Observatory.*) 4to. La Plata, 1925–27

Lembang (Java), Bosscha-Sterrenwacht:
Annalen. Vol. 2, Gedeelte 2; Vol. 3, Gedeelte 1.
(*Observatory.*) 4to. Bandoeng, 1927–28
Vol. 2, Ged. 2. Photographic Photometry.
Vol. 3, Ged. 1. Second Catalogue of Radial Velocities, compiled by J. Voûte.

Lemberg (Lwów), Observatorium der Technischen Hochschule:
Radio telegraphische Bestimmung der Geographischen Länge von Lemberg (Lwów) Observatorium . . . . von Prof. Dr. L. Grabowski.
(*Observatory.*) 4to. Lemberg, 1927

Leningrad, Russian Amateur Society for the Study of the Universe ("Mirovédénié"):
Publications of the Astronomical Section, Nos. 1, 2.
(*Society.*) 8vo. Leningrad, 1927

Leningrad, Société Astronomique de Russie:
Bulletin. Livraison 26, No. 2.
(*Society.*) 8vo. Moscow, 1927

London, Meteorological Office:
Geophysical Memoirs. Nos. 35, 36, 40.
(*Director.*) 4to. London, 1927
No. 35. C. Chree and R. E. Watson, A Comparison of the Records from British Magnetic Stations, Underground and Surface.
No. 36. J. M. Stagg, On Magnetic Fluctuations and Sunspot Frequency.
No. 40. J. M. Stagg, Day Recurrence Interval in Magnetic Disturbance.

London, Royal Geographical Society:
New Geodetic Tables for Clarke's Figure of 1880, with transformation to Madrid 1924, and other figures. (R.G.S. Technical Series, No. 4.)
(*Purchased.*) 8vo. London, 1927

Louvain University, Laboratoire d'Astronomie et de Géodésie:
Publications. Vols. 2, 3.
(*Laboratory.*) 8vo. Louvain, 1926–27

Madison (Wis.), Washburn Observatory:
Publications. Vol. 15, Parts 1, 2.
(*Observatory.*) 4to. Madison, 1928
Vol. 15, Parts 1, 2. Photoelectric Photometry of Stars.

Manchester, Godlee Observatory:
Annual Report for the years 1923–27.
(*Observatory.*) 8vo. Manchester, 1928

Martens (Erik):
A research on the spherical dynamical equilibrium-distribution of stars of unequal masses.
(*Author.*) 8vo. Göteborg, 1928

Mauritius, Royal Alfred Observatory:
Miscellaneous Publications. No. 6.
(*Observatory.*) Fol. Port Louis, 1927
No. 6. The Cyclone of February 24 to March 3, 1927.

Melbourne Observatory:
Hourly Values of the Magnetic Elements at Toolangi in 1925.
(*Observatory.*) 4to. Melbourne, 1927

Mémery (Henri):
——: *Contribution à l'étude des variations périodiques de la température. Leur cause probable.
(*Author.*) 8vo. Paris, 1921
——: *Sur certaines périodicités des taches solaires indépendantes de la période undécennale.
(*Author.*) 8vo. Paris, 1923

Mémery (Henri)—*continued:*

—— : *Nouvelles recherches sur les variations périodiques des taches solaires indépendantes de la période undécennale.
(*Author.*) 8vo. Paris, 1924

—— : *Notes sur la recherche de périodes météorologiques analogues aux périodes solaires.
(*Author.*) 8vo. Bordeaux, 1926

Meudon, Observatoire Physique de Paris:
Annales. Tome 7.
(*Observatory.*) 4to. Paris, 1926

Mexico, Sociedad Cientifica "Antonio Alzate":
Annuario Astronómico y Meteorológico para 1927.
(*Society.*) 8vo. Mexico, 1926

Michelson (A. A.):
Studies in Optics.
(*Purchased.*) 8vo. Chicago, 1927

Milan, Reale Specola di Brera:
Contributi Astronomici. No. 13.
(*Observatory.*) 8vo. Milano, 1927

Mitchell (S. A.) and C. G. Abbott:
The Fundamentals of Astronomy.
(*S. A. Mitchell.*) 8vo. New York, 1927

Naples, Società Reale (R. Accademia delle Scienze):
Atti, serie seconda. Vol. 17.
(*Society.*) 4to. Napoli, 1927

Nashville, Tennessee, Academy of Science:
Journal, Vol. 3, No. 1. Edward Emerson Barnard Memorial Volume.
(*Academy.*) 8vo. Nashville, 1928

Navarro (Manuel Sánchez):

—— : *Actual co-operación de la compañía de Jesús a los estudios sismólogicos.
(*Author.*) 4to. Barcelona. [*s.d.*]

—— : La estación sismológica de Cartujà (Granada) y su labor cientifica (1903–1928).
(*Author.*) 8vo. Madrid, 1928

Newton (Isaac):
[Russian translation of] Principia, Books I, II, III, by A. N. Kriloff [from a Latin edition of 1871].
(*A. N. Kriloff.*) 4to. Petrograd, 1915–16

New York, American Geographical Society:
The School of Surveying of the American Geographical Society of New York.
(*Society.*) 8vo. New York, 1927

Nilsson (Gerhard):
Die Ursache des Sonnenlichts und der Sonnenwärme: das Universum in neuer Beleuchtung.
(*Author.*) 8vo. Kopenhagen, 1928

Noumerov (B.):
The Program of Talcott's Method for determining the Latitude.
(*Astronomical Institute.*) 8vo. Leningrad, 1927

Ölander (V. R):
*Die Eigenbewegungsverhältnisse des Sternhaufens in der Coma Berenices.
(*Author.*) 8vo. Helsingfors, 1927

Padua, Regio Osservatorio Astronomico:
*Pubblicazioni. Nuovo Serie, No. 1.
(*Observatory.*) 8vo. Venezia, 1926

Palermo, Reale Osservatorio:
Pubblicazioni . . . . Memorie. Nos. 23–34, 36–42, 45, 46.
(*Observatory.*) 8vo. Palermo, 1910–27

Paris, Bureau International des Poids et Mesures:
La création du Bureau International des Poids et Mesures et son œuvre. Ouvrage publié à l'occasion du cinquantenaire de sa fondation par les soins de Ch.-Ed. Guillaume, Directeur du Bureau.
(*Bureau.*) 8vo. Paris, 1927

Paris, Observatoire:
Carte photographique du Ciel. Zones +18°, +20° (14 charts).
(*Observatory.*)

Philadelphia, American Philosophical Society:
Proceedings. Vol. 65, No. 5 (Supp.), Vol. 66 (200th Anniversary volume).
(*Society.*) 8vo. Philadelphia, 1926–27

Przybyllok (E.):
Über die Ursachen des Nichtperiodischen Teiles der Polhöhenschwankungen.
(*Author.*) 8vo. Halle, 1927

Purey-Cust (H. E.):
Sumner's Method. Second edition.
(*Author.*) 8vo. London, 1928

Renaux (J.):
Méthode nouvelle de perturbations spéciales.
(*Author.*) 8vo. [——]

Rio de Janeiro, Observatorio Nacional:
——: Boletin Magnetico, 1926. Publicado no anno do centenario do Observatorio Nacional, 1927.
(*Observatory.*) Fol. Rio de Janeiro, 1927
——: Medidas micrometricas de estrallas duplas effectuadas durante os annos de 1924 a 1926 na equatorial de Cooke de 46 cms. Pelo Assistente-Chefe Domingos F. da Costa.
(*Observatory.*) Fol. Rio de Janeiro, 1927

Rome, Pontificia Accademia delle Scienze:
P. G. Hagen, S.J., 1847–1927. Al Rev. Padre Giovanni Hagen, S.J., Direttore della Specola Vaticana, la Pontificia Accademia delle Scienze a festeggiare il compimento dei suoi LXXX anni.
(*G. Hagen.*) 8vo. Roma, 1927

Rome, Società Italiana per il Progresso delle Scienze:
——: Annuario 1927 (XX dalla sua fondazione).
(*Society.*) 8vo. Roma, 1927
——: Atti. Indici della prima serie (Vol. I–X, 1907–1919). Terdicesima Riunione, Napoli, 1924; Quattordicesima Riunione, Pavia, 1925; Quindicesima Riunione, Bologna, 1926.
(*Society.*) 8vo. Roma, 1925–27

Rome, Specola Vaticana:
——: Carta fotografica del Cielo. Zones +55°, +57° (42 charts).
(*Observatory.*)
——: Catalogo Astrografico 1900. Vol. IX, +56°. Appendix I, II.
(*Observatory.*) 4to. Roma, 1920, 1921, 1926
——: Pubblicazioni. Vol. 10, Part 3 (*see* **Hagen, J. G.**).
——: Atlas Stellarum Variabilium (*see* **Hagen, J. G., and M. Esch**).

Rupert-Jones (J. A.):
Tidal Research. The Adaptation of Sir Isaac Newton's Tidal Laws to the Prediction of the Height of High Tides.
(*Author.*) Fol. Southampton, 1928

San Fernando, Instituto y Observatorio de Marina:
——: Astrographic Catalogue 1900·0. Tomo VII (zona −8°).
(*Observatory.*) 4to. San Fernando, 1928
——: Carta Fotográfica del Cielo. Zone −3° (20 charts).
(*Observatory.*)

Schlesinger (Frank):
General Catalogue of Stellar Parallaxes compiled . . . at Yale University Observatory. Edition of 1924, including all determinations available in January of that year.
(*Yale University Observatory.*) 4to. [New Haven], 1924

Schnabel (Paul):
Berossos und die Babylonisch–Hellenistische Literatur.
(*Purchased.*) 8vo. Berlin, 1923

Schoch (Karl):
Planeten-Tafeln für jedermann zur Berechnung der geometrischen Örter der grossen Planeten (und des Mondes) für den Zeitraum von 3400 v. Chr. bis 2600 n. Chr., ohne Anwendung der Logarithmen und trigonometrischen Funktionen bis auf ein Zehntel Grad unter besonderer Berücksichtigung der Babylonischen Astronomie.
(*Author.*) 4to. Berlin-Pankow, 1927

Schoenberg (Erich):
*Über die Strahlung der Planeten.
(*Author.*) 8vo. Berlin, 1926

Science Abstracts:
Vols. 1–9.
(*A. E. Levin.*) 8vo. London, 1898–1906

See (T. J. J.):
*Discovery that Æther Waves are the cause of Universal Gravitation.
(*Author.*) 4to. [*s.l.*], 1927

Sticker (Bernhard):
Helligkeits-Verzeichniss von 620 Sternen, 8. bis 12. Grösse; vergleichende Untersuchungen über das Küstner'sche Grössensystem.
(*Author.*) 8vo. Berlin und Bonn, 1928

Störmer (Carl):
*On an Aurora Curtain of violet-gray colour situated at a high Altitude, photographed on September 8th, 1926.
(*Author.*) 8vo. Leipzig, 1927

Swarthmore College, Penn., Sproul Observatory:
Publications. No. 9.
(*Observatory.*) 8vo. Philadelphia, 1928
No. 9. Report of the Swarthmore College Expedition to observe the total solar eclipse of Jan. 14, 1926.

Tachkent, Observatoire Astronomique et Laboratoire Astronomique de l'Université de l'Asie Centrale:
Publications. Nos. 1–4.
(*Observatory.*) 8vo. Tachkent, 1927

Tacubaya, Observatorio Astronómico:
——: Catalogo Astrofotografico, 1900·0. Tomo I, Zona −15°.
(*Observatory.*) Fol. Mexico, 1923
— —: El Observatorio Astronómico Nacional en su Quincuagésimo Aniversario.
(*Observatory.*) 8vo. Tacubaya, D.F., 1928

Talence, Observatoire:
Bulletin. Série 2, Nos. 1–3; Supplément au No. 3.
(*Observatory.*) 8vo. Bordeaux, 1928

Thost (E.):
*Das kinematographische Aufnahmeverfahren und seine Nutzbarmachung für die Astrophysik.
(*Author.*) 8vo. Berlin, 1927

Tiflis, Geophysikalisches Observatorium Georgiens:
Seismische Abteilung. Nos. 1–5.
(*Observatory.*) 8vo. Tiflis, 1927

Tortosa, Observatorio del Ebro:
El Observatorio del Ebro. Idea general sobre el mismo por el Sub-director R. P. Ignacio Puig, S.J.
(*Observatory.*) 8vo. Tortosa, 1927

Toulouse, Observatoire Astronomique:
Carte Photographique du Ciel. Zones +5°, +7°, +9° (8 charts).
(*Observatory.*)

Turner (Mrs. Dawson):
An A.B.C. of Astronomy, or Lessons given to her Grandchildren.
(*Mrs. Grove-Hills.*) Fol. typescript [*s.d.*]

Uccle, Observatoire Royal de Belgique:
Carte photographique du Ciel. Zones +33°, +35°, +37°, +39° (20 charts).
(*Observatory.*)

Upsala, Kongliga Vetenskaps Societet:
Nova Acta. Series IV. Volumen extra ordinem editum.
(*Society.*) 4to. Upsala, 1927

Virginia University, Leander McCormick Observatory:
*Publications. Vol. 4.
(*Observatory.*) 4to. Washington, 1927

Washington, National Academy of Sciences:
Memoirs. Vols. 3, 4, 5; 13, 14, 21, 22.
(*Academy.*) 4to. Washington, 1884–86, 1927

Wegner (Udo):
——: *Über die statistische Reihe vom Charlierschen A=Typ und die Boltzmannsche Gleichung.
(*Berlin, Rechen-Institut.*) 8vo. Berlin, 1927
——:*Über die Integralgleichung des Strahlungsgleichgewichtes und deren Verallgemeinerung.
(*Berlin, Rechen-Institut.*) 8vo. Berlin, 1927
——: *Ein weiterer Beitrag zur Integralgleichung des Strahlungsgleichgewichtes und deren Verallgemeinerung.
(*Berlin, Rechen-Institut.*) 8vo. Berlin, 1927

Weir (John W.):
Comets and the Sun: New Theories regarding their structure.
(*Author.*) 4to. London, 1927

Whyte (Charles):
The Constellations and their History.
(*Purchased.*) 8vo. London, 1928

Wilkens (A.):
——: *Untersuchungen zu einer Störungstheorie der Planeten der Jupitergruppe.
(*Author.*) 8vo. Heidelberg, 1918
——: *Hugo von Seeligers wissenschaftliches Werk.
(*Author.*) 4to. München, 1927
——: *Zur Erklärung der Planetoidenlücken im Sonnensystem.
(*Author.*) 8vo. München, 1927

PHOTOGRAPHS, ETC., PRESENTED TO THE SOCIETY.

Mrs. J. R. Abbott. Framed portrait of Copernicus.
The Astronomer Royal. Enlarged print of Solar Corona, 1927 June 29.
Hamburg Observatory. One print of inner Corona and three prints and two transparencies of outer Corona, 1927 June 29, Jokkmokk.
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Mount Wilson Observatory. Five positives on films of nebulæ.
(*Dr. E. P. Hubble.*)

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